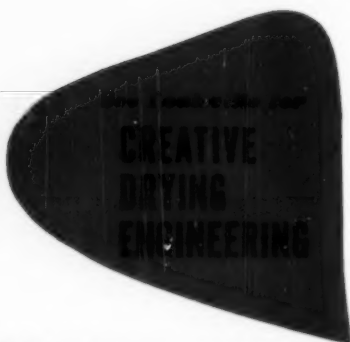


**AUGUST 1952**

# **Chemical Engineering Progress**

**PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS**



## LOUISVILLE DRYER saves \$45,000 yearly for a leading pharmaceutical plant

**KNOW THE  
RESULTS  
before you buy!**

### FORMER DRYER

Installed cost .....\$17,800  
Drying time.....24 hrs.  
Drying cost.....\$0.354 per 100 lb.  
(space required, 950 sq. ft.)

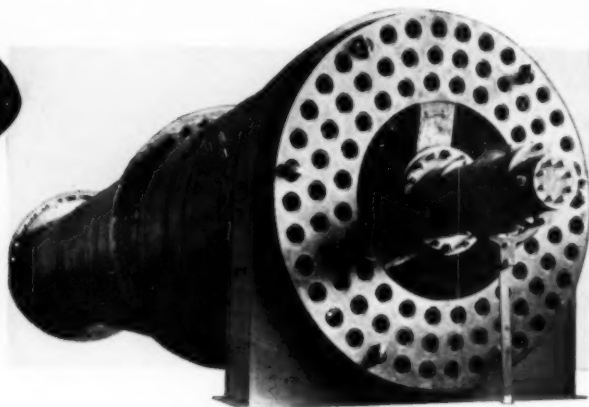
### LOUISVILLE DRYER

Installed cost .....\$29,000  
Drying and cooling time.....45 min.  
Drying cost.....\$0.123 per 100 lb.  
(space required, 300 sq. ft.)

### YEARLY SAVINGS

### IN DRYING COSTS

### ALONE... \$8,300



45 minutes—instead of almost 24 hours for drying!  
Contamination reduced to zero—no need for reprocessing  
90,000 lb. of crystalline chemical every year—  
at a cost of 50c per 100 lb.

It all happened when a Louisville engineer examined this plant's old batch type drying process, and recommended the installation of a specially-designed Louisville dryer. The drying method was pre-tested in our own research laboratories and pilot plant for its ability to "deliver the goods."

If high drying costs and low drying performance are bothering you these days, call in a Louisville engineer. There is no obligation.

Ask for new treatise on subject of rotary dryers

#### Other General American Equipment:

Turbo-Mixers, Evaporators, Dewaterers,  
Towers, Tanks, Bins, Filters,  
Pressure Vessels



### Louisville Drying Machinery Unit

Over 50 years of creative drying engineering  
**GENERAL AMERICAN TRANSPORTATION  
CORPORATION**

Dryer Sales Office: Hoffman Bldg., 139 So. Fourth Street  
Louisville 2, Kentucky  
General Offices: 135 South La Salle Street, Chicago 90, Illinois  
Offices in all principal cities  
In Canada: Canadian Leominde Company, Ltd.  
Kingston, Ontario

# Chemical Engineering Progress

Volume 48

Number 8



AUGUST

1952

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for the *First* time—  
predictable performance  
meters in "teardrop"  
flow ranges

Here, for the first time, is a laboratory flow meter which makes possible dependable and predictable flow rate measurement—even at a fraction of a cc/min. It employs the new F&P "Tri-Flat" Pyrex glass tube, featuring three lands parallel to the tube axis to provide a tangential guide for a free spherical float. Steady float action—without bounce or wobble—assures constant flow coefficient. For the first time, low flow rate measurements are not only predictable, but repeatable, with high accuracy—outmoding all other laboratory flow rate meters.

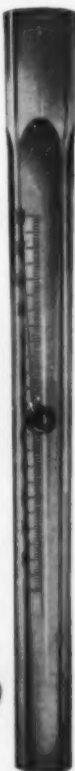
Performance data for "Tri-Flat" metering elements has been compiled in a new engineering handbook. Laboratory use of the new predictable performance elements and the handbook is simple and convenient. Previously required check calibrations can be forgotten.

A limited number of Laboratory Sets has been prepared to introduce this revolutionary development. These sets cover a flow range of 0.07 to 900 cc/min. of water or 5 to 37,000 std. cc/min. of air.

### Each set includes:

- Five sizes of TRI-FLAT meters with standard taper ground glass joints.
- Matching, precision spherical sapphire and constant density floats.
- Engineering TRI-FLAT data handbook.
- Fine hardwood carrying case.

Priced complete at \$95 f.o.b. Hathero. Avoid delay in bringing the advantages of this program to your laboratory by placing order now.



**FISCHER & PORTER  
COMPANY**

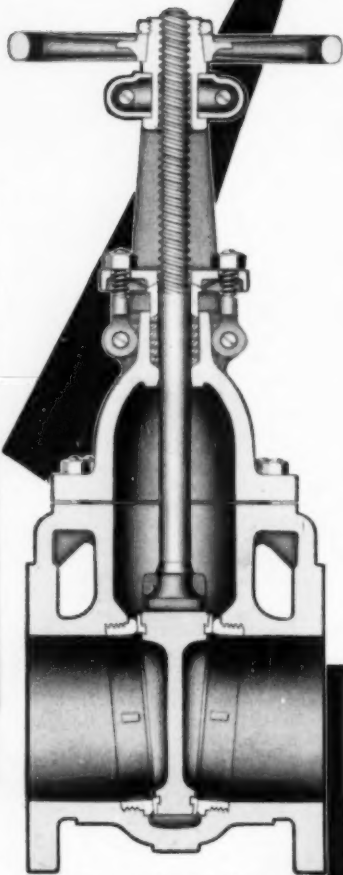
180 County Line Road, Hathero, Penna.

# cut the high cost of corrosion

IN MANY SERVICES...WITH

## CRANE *Ni-Resist*

### CAST IRON GATE VALVES



Cross-section 4 to 8 in. sizes; bolted bonnet joint; flanged ends.

Here is a line of "cast iron" gate valves with a special talent for resisting corrosion, erosion and wear. Use them with safety where the strength of ordinary cast iron is adequate—in soda and sulfate pulp mill service—on creosote lines in wood treating processes—for handling sour distillates and crudes in petroleum refining—and many similar services.

Clue to the extra staying-power of Crane Ni-Resist Cast Iron Valves is in their make-up (approximately 14% nickel, 2½% chromium, and 6% copper)—and in their 18-8 Mo Alloy Steel stem and seating faces. Not to be overlooked is the fine Crane design that gives you a strong body and bonnet without excessive weight, a well-proportioned stem with precision-cut threads, a sturdy yoke, and the dependable disc-stem connection that assures smooth operation and tight seating of the solid wedge disc. Ask your Crane representative for full details, or see your Crane Catalog.

#### THE CRANE NI-RESIST LINE

Working Pressures:

Cold Water, Oil, or Gas, Non-shock

Screwed Valves—225 pounds

Flanged Valves—200 pounds

Available in sizes ½ to 8 in. All have solid wedge disc, with outside screw and yoke. Sizes ½ to 3 in. have clamp type bonnet joint and one-piece bolted gland. Sizes 4 to 8 in. have conventional bolted bonnet joint and two-piece bolted gland.



No. 1671 with Bolted Bonnet Joint, Flanged ends only. Sizes 4, 6 and 8 in.



No. 1670 with Clamp Type Bonnet Joint with screwed ends. Sizes ½ to 2 in. Also with flanged ends 1 to 3 in.

The Complete Crane Line Meets All Valve Needs. That's Why More Crane Valves Are Used Than Any Other Make!

## CRANE VALVES

CRANE CO., General Offices: 836 S. Michigan Ave., Chicago 5, Illinois  
Branches and Wholesalers Serving All Industrial Areas

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



# Girdler Process News



## GIRDLER DESIGNS AND BUILDS New plastics materials plant for B. F. Goodrich Chemical Co. in record time!

**H**ERE is the fourth major chemical project completed by Girdler for B. F. Goodrich Chemical Company... a plant now producing large quantities of Geon® polyvinyl materials.

Based on Girdler's past performance, B. F. Goodrich Chemical assigned Girdler a "package" contract for process engineering and construction. The plant was completed economically and in record time to meet the increased demand

for Geon materials for consumer and defense use.

For process plants in the chemical, natural gas, and petroleum industries, Girdler assumes unit responsibility for design, process engineering, and construction. Such coordination centralizes responsibility, and saves time.

To assure successful results, call on Girdler in the *planning stages* of your processing facilities.

\*HYGIRTOL is a trade mark of The Girdler Corp.

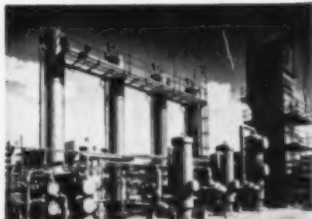
## The **GIRDLER** Corporation

LOUISVILLE 1, KENTUCKY  
Gas Processes Division

**GAS PROCESSES DIVISION:** *Designers, Engineers, and Constructors for the Petroleum and Chemical Industries*

**VOTATOR DIVISION:** *Processing Apparatus for the Food and Chemical Industries*

**THERMEX DIVISION:** *Industrial High Frequency Dielectric Heating Apparatus*



**Hydrogen Plant.** This plant, the second Girdler HYGIRTOL® unit purchased by Lever Brothers Company, assures a dependable source of high-purity hydrogen for hydrogenation of vegetable oils at Lever's new Los Angeles plant. Instruments control the process, and only one man is required to keep the plant in operation, furnishing hydrogen at any desired rate. Purity generally exceeds 99.8%, and operation is safe, quiet, and clean.



**Synthesis Gas Plant.** Girdler has broad experience in handling complete "process packages", covering design and construction of process plants involving very high operating pressures, high temperature reactions, and corrosive substances. This synthesis gas plant is a unit of a complete synthetic nitrogen fertilizer plant which operates with a lower unit energy input than any similar plant in existence.

### Want More Information?

Girdler's Gas Processes Division designs and builds plants for the production, purification, or utilization of chemical process gases; purification of liquid or gaseous hydrocarbons; manufacture of organic compounds. Write for Booklet G-35, The Girdler Corporation, Gas Processes Division, Louisville 1, Kentucky. District Offices: New York, Tulsa, San Francisco. In Canada: Girdler Corporation of Canada Limited, Toronto.



take a **CLOSER LOOK** at

**B&W**

# ALLOY TUBING

for high temperature applications

CARBON-MOLY • CROLOY  $\frac{1}{2}$  • CROLOY  $1\frac{1}{4}$

CROLOY 2 • CROLOY  $2\frac{1}{4}$  • CROLOY 3-M • CROLOY 5

CROLOY 5-SI • CROLOY 7 • CROLOY 9-M

All of these intermediate alloys, developed expressly for high temperature services, are being used extensively in a wide variety of chemical processing applications. All have earned universal acceptance and praise for giving optimum service satisfaction with economy over the years. The accompanying table shows the extensive range of temperature, pressure, corrosion, and oxidation conditions met by B&W Alloy Tubing. Technical data on these analyses is contained in Bulletin TB-12, available upon request. Call on Mr. Tubes—your B&W Tube Representative—to get the benefit of the extensive tubing service he represents, on your specific tubing problems

**CARBON-MOLY** — 0.50% Mo—For services to 1050F requiring higher creep strength than carbon steel with no increase in corrosion or oxidation resistance.

**CROLOY  $\frac{1}{2}$**  — 0.60% Cr, 0.50% Mo—For operating conditions to 1075F requiring properties superior to carbon-moly with respect to graphitization and creep strength.

**CROLOY  $1\frac{1}{4}$**  — 1.25% Cr, 0.50% Mo, 0.75% Si—Economic grade good creep strength properties up to 1100F. Somewhat more corrosion resistant than chromium-free steels.

**CROLOY 2** — 2% Cr, 0.50% Mo—Economic grade for resisting both oxidation and corrosion, with excellent high-temperature strength, up to 1150F.

**CROLOY  $2\frac{1}{4}$**  — 2.25% Cr, 1.00% Mo—Exceptionally high creep strength up to 1175F for polymerization and high pressure cracking. Otherwise similar in properties and characteristics to Croloy 2.

**CROLOY 3-M** — 3% Cr, 0.90% Mo—Somewhat better creep properties, and resistance to corrosion and oxidation up to 1175F than Croloy 2.

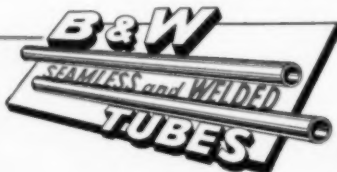
**CROLOY 5** — 5% Cr, 0.50% Mo—For operating conditions up to 1200F where corrosion resistance is a primary requirement—with creep strength and oxidation resistance superior to Croloy 2.

**CROLOY 5-SI** — 5% Cr, 0.50% Mo, 1.50% Si—For operating conditions up to 1300F where oxidation resistance is a primary requirement. Excellent resistance to scaling under straight oxidizing conditions.

**CROLOY 7** — 7% Cr, 0.50% Mo, 0.50-1.00% Si—For operating conditions up to 1250F where corrosion resistance is the primary requirement. Somewhat more oxidation resistant than Croloy 5.

**CROLOY 9-M** — 9% Cr, 1% Mo—For severe operating conditions up to 1300F where high corrosion and oxidation resistance are essential as in hydrogenation processes,

Steels from CROLOY  $1\frac{1}{4}$  upward are electric furnace alloy steels which are normally cleaner and of better quality than open hearth steels. This contributes to greater reliability and improved creep properties at elevated temperatures.



## THE BABCOCK & WILCOX COMPANY TUBULAR PRODUCTS DIVISION General Offices & Plants

Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing  
Alliance, Ohio—Welded Carbon Steel Tubing

Sales Offices: Beaver Falls, Pa. • Boston 16, Mass. • Chicago 3, Ill.  
Cleveland 14, Ohio • Denver 3, Colo. • Detroit 26, Mich. • Houston 19, Texas  
Los Angeles 17, Cal. • New York 16, N. Y. • Philadelphia 2, Pa.  
St. Louis 1, Mo. • San Francisco 3, Cal. • Syracuse 2, N. Y.  
Toronto, Ontario • Tulsa 3, Okla.

TA-1685

Where purification by distillation is ineffective, impractical or impossible

CONSIDER

**Magnesol**  
BRAND MAGNESIUM SILICATE

to remove acidic residues, color, odor  
or traces of moisture from liquids by **Adsorption**

Useful "chemical-process tool", MAGNESOL BRAND magnesium silicate has many potential applications wherever it is necessary to decolorize, deodorize, clarify or purify organic solvents, oils, fats, waxes, etc. by adsorption rather than distillation.

Typical examples (which may suggest uses in your processes) include such diverse applications as:

- Removal of residual organic acids from plasticizers.
- Reclaiming industrial solvents.
- Purification of dinityl maleate used in the manufacture of fiber-glass reinforced plastics.
- Bleaching vegetable and animal oils.
- Re-refining of Silicone oil.

A highly adsorptive synthetic magnesium silicate, MAGNESOL\* is made under close chemical control. Its dependably uniform properties, high effectiveness in small quantities and modest price commend it wherever an alkaline (pH 7.5-8.5) adsorbent is required.

**SEND FOR TECHNICAL DATA SHEET  
AND TEST SAMPLE**

Kindly describe your problem so that our Technical Service Division can give you the maximum benefit of our many years of MAGNESOL manufacture and application.

\*MAGNESOL is the registered trade mark of Food Machinery and Chemical Corporation for its brand of magnesium silicate adsorptive powder.



Need a FLOW-PROMOTOR  
or ANTI-CAKING AGENT?

MAGNESOL'S finely-divided structure, forms an intimate, "slippery" coating on powdered material, such as foods, condiments, toiletries, detergent mixtures, insecticides, molding powders, heavy and fine hygroscopic chemicals, etc. Its mildly desiccant activity lengthens the "shelf life" of packaged goods, prevents agglomeration of bag and bulk products. Write for samples, specifying your potential use.



**WESTVACO CHEMICAL DIVISION**  
FOOD MACHINERY AND CHEMICAL CORPORATION

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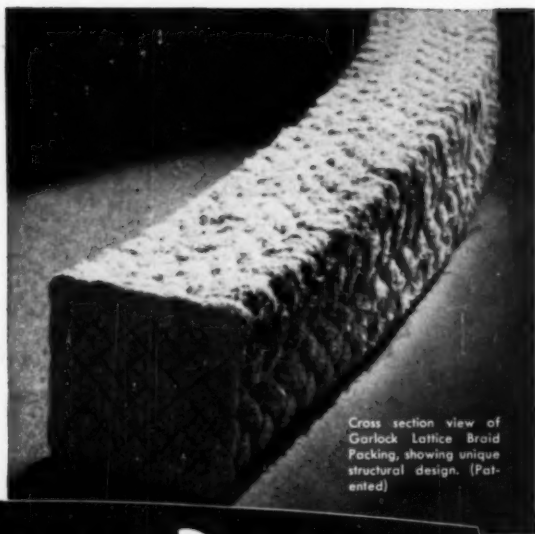
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ST. LOUIS, MO. • POCATELLO, IDAHO • LOS ANGELES, CALIF. • NEWARK, CALIF.



**For Long  
Trouble-Free Service**

**USE**

# LATTICE-BRAID PACKING



Cross section view of Garlock Lattice Braid Packing, showing unique structural design. (Patented)



GARLOCK 751 (cotton) Lattice-Braid Packing for hot or cold water.



GARLOCK'S specially designed Lattice-Braiding machines.

## The Greatest Improvement Ever Made in Braided Packings!

The strands of Garlock Lattice-Braid packings are braided *through and through* on specially designed braiding machines. Since all strands are strongly linked together into a single unit, they are firmly held together even when the packing is worn far beyond the limits of wear of ordinary braided packings.

This exclusive lattice braiding also provides unusual flexibility and semi-automatic pressure action which keeps the packing properly adjusted in the stuffing box. Longer service with less attention.

Garlock Lattice-Braid is manufactured from flax, cotton, asbestos, wire-inserted asbestos and "Teflon"—for various types of service. Furnished in ring, coil or on reels.

*Write today for the new Lattice-Braid Folder.*

THE GARLOCK PACKING COMPANY  
PALMYRA, NEW YORK

In Canada: The Garlock Packing Company  
of Canada Ltd., Toronto, Ont.



# GARLOCK

**PACKINGS, GASKETS, OIL SEALS,  
MECHANICAL SEALS,  
RUBBER EXPANSION JOINTS**

# \$ulfur

by-product with a big dividend

recovered with

## FOSTER WHEELER EQUIPMENT



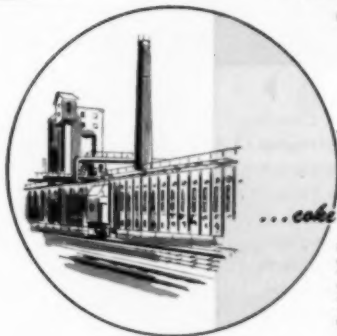
...from oil and gas fields

$H_2S$  content of sour gas converted to elemental sulfur. A Foster Wheeler sulfur recovery plant in one location is producing over 300 tons/day of elemental sulfur.



...petroleum refineries

$H_2S$  gases previously "flared" and the sulfur wasted, now recovered. Two Foster Wheeler sulfur recovery plants for this service now under construction.



...coke ovens

Removal of  $H_2S$  from coke oven gas not only enhances the value of the gas but provides a source of elemental sulfur. A Foster Wheeler sulfur recovery plant is in operation on this service.

The unprecedented demand for Sulfur has reached a point where the world's available supply is seriously threatened. Thus, the need to find new sources for this vital element becomes one of the major items on today's agenda for full-scale production for both defense and civilian needs.

Fortunately, there is a great new source. Instead of allowing it to vanish into thin air, Sulfur is being recovered profitably from  $H_2S$  bearing gases with Foster Wheeler equipment. A quarter million tons of Sulfur per year will be recovered by Foster Wheeler plants installed or now under construction.

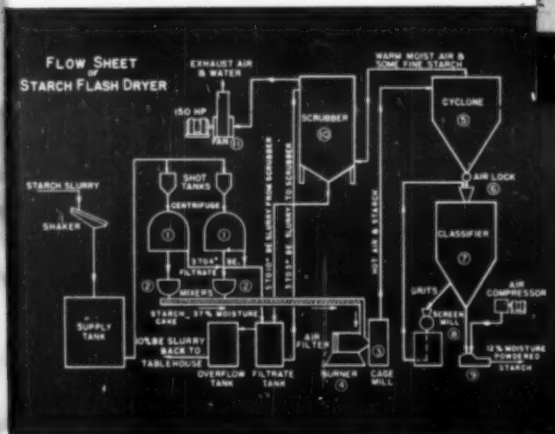
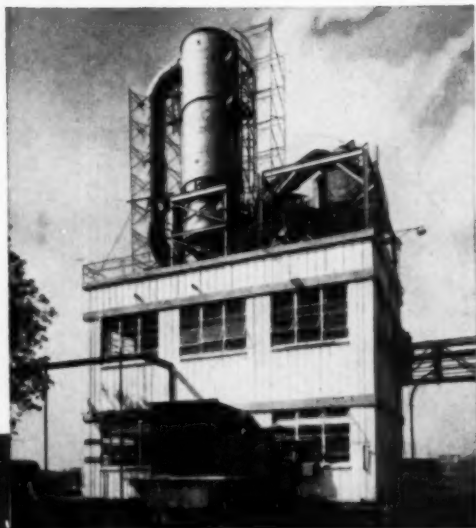
## FOSTER WHEELER

165 BROADWAY, NEW YORK 6, N. Y.



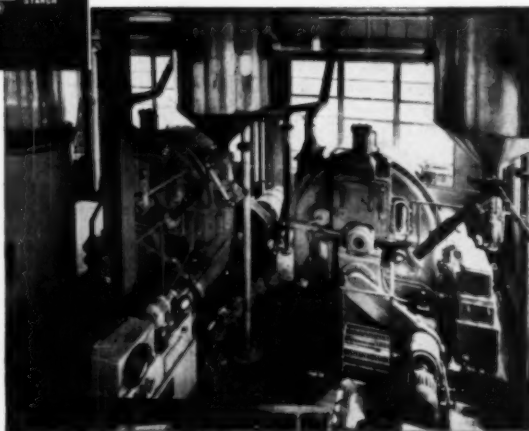
# AMERICAN MAIZE-PRODUCTS COMPANY of Hammond, Ind. revolutionizes starch production with new flash drying unit and two BAKER PERKINS Centrifugals

New flash drying plant of the American Maize-Products Company is the first commercial application of flash drying to corn starch. The plant can handle approximately 300,000 lbs. of corn starch daily, an increase in the Company's starch drying capacity of more than 50%. And the quality of the product is far better than that produced by the old kiln method of drying. Two BAKER PERKINS ter Meer Centrifugals dewater starch slurry to a moisture content of 35% for the flash drying unit.



Flow sheet diagram of the new flash drying plant. This new method of drying corn starch is faster and more efficient than any other drying method now used in the corn refining industry. Production is higher; capital and operating costs are lower. And the two BAKER PERKINS Centrifugals shown in the diagram help keep production high and costs low for the American Maize-Products Company.

These two BAKER PERKINS ter Meer Centrifugals play a vital part in the successful operation of the flash drying unit. In this installation, they are fully automatic, but they can be provided with manual controls if necessary. A simple cycle controller makes complicated centrifugation cycles easy, and the control cycle will compensate for most any process variables. BAKER PERKINS Centrifugals are available in several capacities for production work as well as in laboratory and pilot plant models.



## BAKER PERKINS INC.

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN



# STRUTHERS WELLS FIRED HEATING EQUIPMENT

*for Dowtherm  
and Other Fluids*

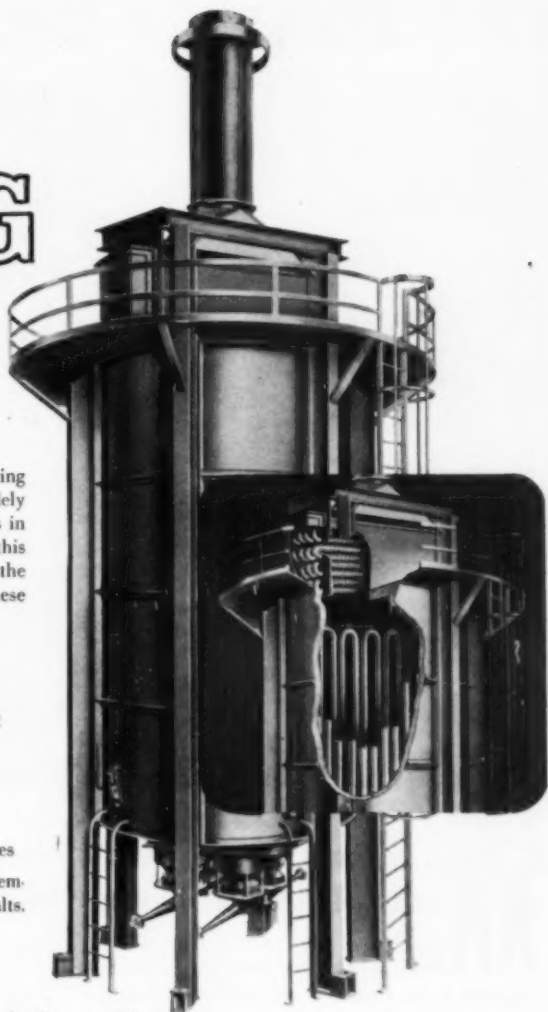
The Struthers Wells forced circulation system utilizing Dowtherm as a heat transfer medium has been widely accepted by the chemical industry and other users in recent years. Scores of large installations in this country, and numerous units abroad, testify to the universal satisfaction of the user. Many of these installations are repeat orders.

This system offers the user:

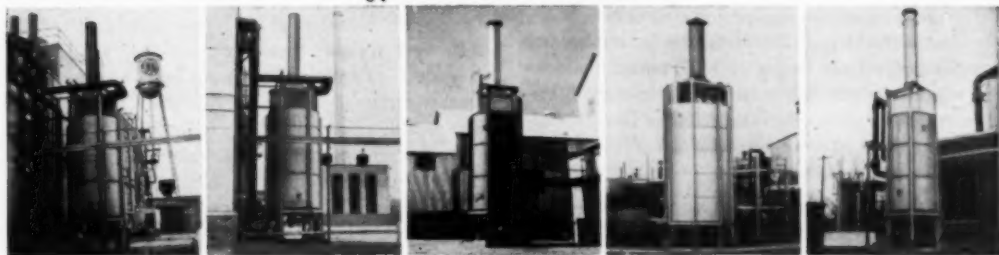
- Proven performance at maximum temperatures
- Trouble-free operation, no coking or overheating of equipment
- High thermal efficiencies
- Close temperature control
- Complete equipment and engineering service
- Moderate initial cost and low maintenance charges

We also supply equipment for heating gases to high temperatures—for superheating steam—heating asphalts, absorption oil and a wide range of services.

Good deliveries are available in standard sizes.



## *Typical Installations*



Write for Bulletin B-25  
on your letterhead,  
please



**STRUTHERS WELLS CORPORATION**  
WARREN, PA.

Plants at Warren, Pa. • Titusville, Pa.  
Offices in Principal Cities

# THE FOURTH DICALITE PLANT



...will add approximately 80% increased production capacity for Dicalite calcined and processed filteraids and fillers

The new plant of the Dicalite Division, Great Lakes Carbon Corporation, at Lampoc, Calif., is now in volume production at a continually increasing rate. It represents over 5 years of engineering, design and construction, and is the largest complete unit for processing diatomite built in the last 22 years. Full designed output will add approximately 80% increased production capacity for Dicalite calcined and processed filteraids, fillers and other materials.

This increased production capacity insures a

plentiful supply of Dicalite products for the future. Users can be confident of dependable delivery, with four plants in operation, chances of interrupted supply are greatly reduced.

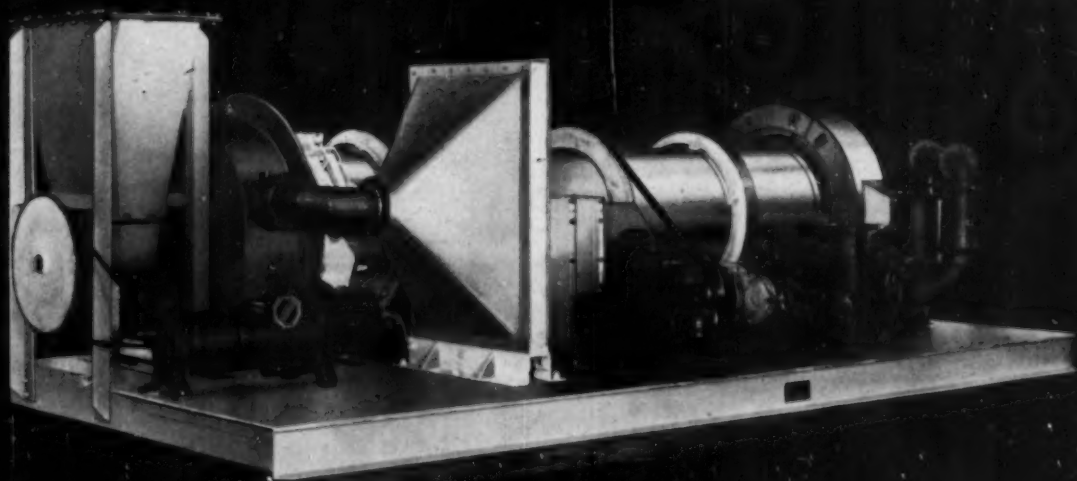
Advanced design of the new plant has afforded greater operating flexibility and extended processing ranges. Specifications for performance and quality of each product are readily maintained. Research data are being accumulated to aid in developing new and improved Dicalite products for future industrial use.

## DICALITE DIVISION

GREAT LAKES CARBON CORPORATION



NEW YORK 17 • CHICAGO 1 • LOS ANGELES 17



**stainless steel**

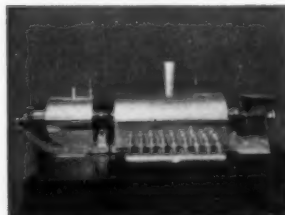
# Anti-Biotic Dryer

**prevents product contamination**

● Of special design, the dryer pictured above removes an organic solvent from a newly developed anti-biotic — avoids product contamination. The drying cylinder is of stainless steel, with ground and sand blasted welds and the flights that lift the material, and cascade it down through the heated air stream, are of special design to assure a smooth interior surface, eliminate corners, and permit the entire interior of the unit to be cleaned, thoroughly and quickly. Complete with feed hopper, variable speed screw feeder, heating coils, air blower, air sterilizing unit, exhaust fan and cyclone dust collector mounted on the same frame to insure permanent alignment of all parts, this unit illustrates Bartlett-Snow's ability to design and build equipment to meet the most exacting requirements. Let us work with you on your next drying problem.



Rotary Cooler with Continuous Interior Flight Permitting the Rate of Cooling to be Controlled by the Speed of Shell Rotation.



Experimental Calciner, Determines the Preferred Operating Conditions Preliminary to Building Full Size Plant Equipment.

DESIGNERS

ENGINEERS

**BARTLETT  
B-SNOW**  
CLEVELAND 5, OHIO

FABRICATORS

ERECTORS

*Dryers • Coolers • Calciners • Kilns*

*"Builders of Equipment for People You Know"*

# Cut CONTROL VALVE MAINTENANCE COSTS!

## For inspection and maintenance Annin Valves remain in the line

The single seat design of the Annin valve body means lower maintenance costs. As shown, the lower half separates from the valve assembly, exposing for inspection or replacement the valve seat, plug and stem—without removing valve from line. No special pipeline crews are necessary. On-the-job inspection and maintenance by plant crews is practical and economical. Valve seat is not threaded and can be replaced without special tools or grinding-in operations. Under severe erosive and corrosive conditions lower half can be easily replaced at small cost compared to total valve investment. This cost-cutting feature applies to *all* Annin Valves—Domotor, Solenoid, and Handwheel types. All give the ultimate in precision *positive* control. If you are interested in lower maintenance, and operating advantages approached by *no other valve*—it will pay you to investigate Annin Valves.

Send for Annin General Catalog 1500B. Explains the exclusive Annin positive control Domotor action. Contains valuable cost-cutting hints, control valve application facts, flow formulas.



The Annin Domotor valves provide positive control of corrosive, erosive fluids and fluids containing semi-solids.

# ANNIN CONTROL VALVES

HERE'S REAL INSURANCE AGAINST WORKMAN CARELESSNESS



# Lapp TUFCLAD



**SOLID**

**CHEMICAL PORCELAIN**

**ARMORED**

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**REINFORCED PLASTIC**

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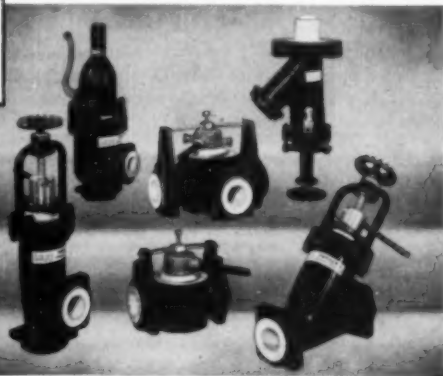
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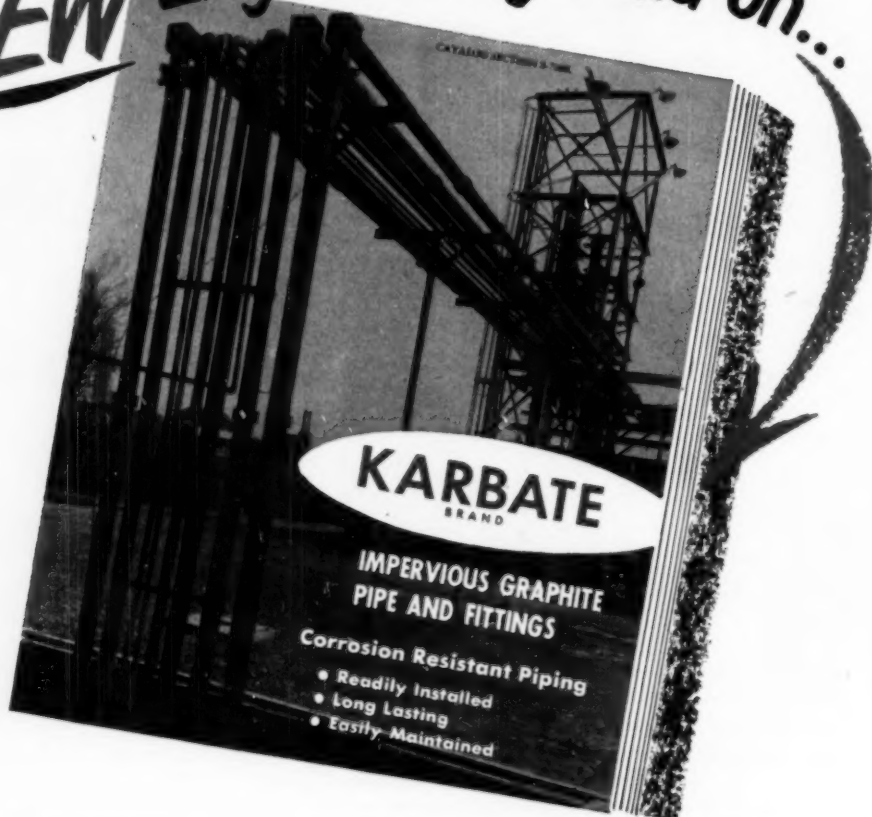
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# OPINION AND COMMENT

## YOUR STAKE IN THE A.I.Ch.E.

**T**O THE young engineer who faces the need for rounded professional development, and to the seasoned executive as well, active participation in the A.I.Ch.E. offers sound and continuing advantages.

The graduate chemical engineer has no difficulty at this time in securing satisfactory employment. Indeed, he will find today that he need not even leave his alma mater to find a suitable job. The concurrence of a huge industrial expansion and a diminishing supply of trained technical men has sent industrial personnel men to every campus in the nation searching out unpledged graduates.

Under these happy conditions the graduate may pick and choose among several employers. He may often choose the type of company, the kind of engineering work, and the section of the country which most appeal to him. He may accept or reject the likelihood of travel in connection with his work, and may even exercise some option in the matter of getting his hands dirty.

One factor or another will sway his choice, and this made, he settles down to new tasks with a will, confidently expecting glowing prospects to materialize. Frequently they don't. And right here there becomes evident a paradox—one which will never be resolved for the engineer who balks at the self-analysis required. The traits which earn superior grades and a degree cum laude at school may be those which, unmodified, limit his progress in industry. Without enumerating these, it can be said that during his entire scholastic career his paramount effort has been a striving for individual honors, without reference to the work of others. The progress of commercial enterprise, however, demands that the engineer pursue his work with constant awareness of the problems of his associates and the development of the entire project. Frequently he must subordinate his individual aspirations to the requirements of the job, and conceal his regret if any is felt.

Progress in this necessary transition from self-emphasis to job-emphasis can be accelerated through membership in the American Institute of Chemical Engineers. Association with other engineers who are making the same adjustments cannot help but suggest new attitudes and more direct methods for making the transition complete. What better meeting place is there for the pursuit of this common purpose than at the local section, or at the regional and annual Institute meetings? Advancement in the profession certainly requires that an engineer keep abreast of developments in technology, especially so in the rapidly growing chemical industry. Here, too, the Institute's regular meetings take the engineer away from brief patrol actions far out on the left flank, directly into GHQ, where he may hear reports from staff officers about new plans and developments along the whole line of the chemical battle. The scope and value of his own duties then show

a clearer perspective and he learns to place the emphasis where it belongs.

So much for what may be called the pivotal benefits of membership. There are others which strict logic might call secondary, but in no sense are they of lesser importance. The ability to write concise reports and letters on technical subjects, to speak effectively before group meetings, and even to conduct such meetings contribute significantly to one's individual advancement and enlist the favorable notice of one's superiors. Attendance at the symposia presented at the Institute's meetings, the preparation of papers for presentation, and active work on its various committees offer a direct path to experience in these fields.

Throughout the industry may be found chemical engineers who, aided by the experience of Institute membership, have moved beyond day-to-day concern with the problems of equipment and process design into positions of greater responsibility. Many are now sales managers, production managers, or research directors, and some have become officers in the same companies where, not so many years ago, equipped with slide-rule, plaid jacket and crew cut, they set out to make a name for themselves.

Those already executives will agree that one of their greatest challenges is to direct the skills and shape the attitudes of young engineers to the end that they become capable of assuming administrative responsibility. Membership by an executive engineer in the A.I.Ch.E. accomplishes a great deal toward this end—it exerts a powerful influence upon the younger engineers, whose emulative drive is at a peak, to join the Institute and the local section. In consequence, their participation in professional activities rapidly increases their value as employees, and as professional engineers in the ways already described.

Many of the symposia planned by the A.I.Ch.E. for the months ahead hold a real interest for the executive group, and will serve equally well as powerful aids in the daily tasks of management, and as preparation for the responsibilities to which our younger engineers aspire.

For example, a symposium to be presented at the Chicago meeting in September on the general theme "Distribution of Chemicals" will cover "Transportation," "Packaging and Labeling," "Advertising," and "Sales Channels." The Cleveland annual meeting in December, 1952, will present a symposium on "Human Relations," a subject whose pressing daily importance is self-evident. "Effective Human Relations," "Human Personality," "Working Harmony," and "Words-Instruments for Human Relations" will be some of the topics covered. These are as undeniably the working tools of executive personnel today just as surely as the slide-rule and nomograph were on the way up through the ranks.

L. P. SCOVILLE

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**TYGON GASKET** — in service against 85% acetic acid, at 160°-175°F lasts over a year compared to a few weeks' service from rubber. Photo courtesy Hoffman-La Roche Inc.

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**PLASTICS AND SYNTHETICS DIVISION**

# CORROSION TESTING

## A Tool of Conservation

E. G. HOLMBERG

Alloy Steel Products Company, Linden, New Jersey

**O**UR purpose in conducting corrosion tests is twofold. First, we must cooperate with the defense effort by determining the proper alloys for our various services, which will have optimum corrosion resistance and require minimum additions of strategically important metals. Second, from the standpoint of economics as well as conservation, we must continue our search for new alloys to provide materials more resistant than those currently available for certain of our chemical processes.

As will be brought out, laboratory corrosion data, developed for various alloy compositions under specific solution conditions, designed to parallel those of a particular plant operation, are frequently found unreliable. To venture an alloy recommendation for a plant service which approximates the conditions in another plant where certain materials are being successfully used, can also be disastrous. This is particularly true when only limited information is available for the effect on solution corrosiveness of such variables as concentration, temperature, velocity, pressure, and the presence of small amounts of impurities.

The sources in descending order of reliability from which data can be obtained (in the absence of directly applicable experience) for making alloy recommendations for a particular production unit solution and operating conditions, can be tabulated as follows:

1. Corrosion tests conducted within vessels or solution lines of a full-scale operating unit.
2. Corrosion tests conducted within a pilot plant built to study the process characteristics.
3. Laboratory corrosion tests conducted in synthetic solutions and in equipment designed to reproduce or approximate conditions that will be encountered within a full-scale unit.
4. Corrosion test data available for materials used to handle solutions of a similar or preferably identical composition, at pressure, temperature and velocity conditions comparable with those that will exist within the new unit.

Obviously, if a chemical process is entirely new, representing an improvement over some previously employed process, or is designed to make an entirely new product, one of the last three methods designated must be employed for selection of the proper materials of construction.

When it is necessary to select alloys for the construction of a new operation by one of these three last methods, experience has indicated that corrosion tests should be conducted after the plant starts producing, to determine the accuracy of the alloy selections and also to evaluate other less expensive alloys. Frequently when first starting a new unit there is a period during which operating "bugs" must be worked out. Unless it is desirable to obtain data for the metal loss suffered by the equipment during this period, corrosion testing should be delayed until smooth unit operation has been achieved.

Many units constructed some ten or more years ago and still in operation today used special alloys then thought to suit the operating conditions. Unless premature failure occurred the plant oftentimes continued to use the originally specified alloys.

We now are learning by check testing in the plant, that the cost of maintenance can be reduced by the use of more satisfactory, less expensive and less highly alloyed materials. Some of these were available at the time the plant was constructed; others have been developed in recent years as the industry gained experience with the particular solution condition.

A well-planned corrosion-testing program is now recognized by manufacturers of chemical products, involving the use of corrosive solutions as essential to meeting their competition because of the large part maintenance can play in determining their product cost. These programs, however, are limited in their ability always to find the most desirable material for some corrosive conditions by the availability of materials being

produced commercially. Materials which have the ultimate properties for a specified set of conditions are those that can be fabricated readily and economically, that have a corrosion resistance which will insure several years of freedom from equipment failure or inefficient operation because of metal loss or product contamination, and that also will not fail mechanically because of physical properties limitations. It must be conceded, however, there are process units operating with equipment constructed of materials which do not satisfy these requirements, but that do represent the most economical selections available.

In an effort to produce better alloys for these applications and also to permit studying the effect of varying the percentage of alloy additions on corrosion resistance, there is need for research programs which will require producers and consumers to function as a team in the production and testing of new alloys under plant process conditions. The accumulated data from such a program would serve to enrich our knowledge of the effect of certain alloy modifications on corrosion resistance to various media and could be expected also to indicate new alloy compositions that would have a broader range of application than materials now commercially produced.

The corrosion data to be presented typify the progress that has been made in determining the proper alloy composition for some applications. They also emphasize, because of minor variations in solution compositions, the hazard of making an alloy recommendation for a particular set of solution conditions based on data or experience for an approximately similar set of solution conditions.

Great care must be used in planning the tests, particularly with respect to the method of securing the specimens in the corrosive environment. Corrosion test racks of special design are frequently necessary. One such assembly, which was used to obtain the data presented in this article, is shown in Figure 1. As is indicated, this design test

### E. G. HOLMBERG

was graduated from the Colorado School of Mines with an E.M. degree in 1932. The three years following graduation were spent teaching engineering subjects. In July, 1935, he accepted a position with the Du Pont Co. as metallurgist at its Belle (W. Va.) plant. In August, 1946, he became chief metallurgist for Alloy Steel Products Co., Linden, N. J., the position he now holds.



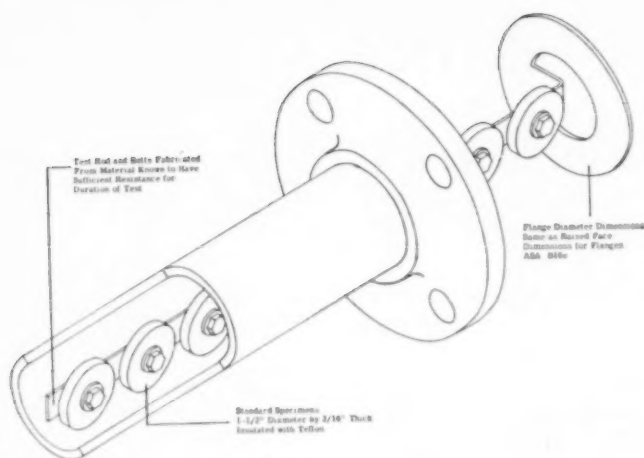


Fig. 1. Corrosion test rod assembly.

rack is secured within a pipe line by means of a ring at one end, bolted between the raised faces of standard pipe flanges. The bolting, supporting rod, and end ring are of an alloy which from available data or previous experience would indicate a satisfactory life under the particular exposure conditions for the duration of the test.

A test period of approximately 60 days usually is recommended. Shorter test periods are recommended when it is known that exposure conditions will be particularly severe on commercially available materials suitable for the construction of this assembly. To eliminate the possibility that attack on some specimens may be accelerated by galvanic



Fig. 2.

TABLE 1—ALLOY COMPOSITION DATA										
Per Cent Nominal Composition										
Alloy	C	Cr	Ni	Mo	Cu	Mn	Si	Su	Zn	W
Stainless Alloys:										
Aloyco 316	0.07	16.00	11.00	2.50		0.45	0.90			
Aloyco 318	0.07	16.00	11.00	2.50		0.45	0.90			
Aloyco 329	0.10	27.00	4.00	1.50		0.55	1.00			
Non-Ferrous Alloys:										
Aluminum										
Chemical Lead	0.10									
Monel										
Special High Alloys:										
Aloyco 35	0.07	20.00	20.00	2.50	4.00	0.45	1.00			
Aloyco 37	0.07	25.00	20.00	3.00	2.75	0.45	1.00			
Worthite	0.07	25.00	20.00	3.00	2.75	0.45	1.00			
Aloyco 31	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 37	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 31	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
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Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 37	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
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Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
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Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
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Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 37	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 31	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 35	0.07	16.00	11.00	2.50	4.00	0.45	1.00			
Aloyco 37	0.07	16.00	11.00	2.50	4.00	0.45	1.00			

behavior, Teflon washers and sleeves are employed to insulate specimens from the bolting and supporting rod.

This method of exposing specimens of various alloys to a specific set of process solution conditions will provide information for general corrosion and also susceptibility to intergranular, pitting, and solution-cell types of attack. The tendency for a solution to cause alloy embrittlement can be roughly determined by performing a bend test on the specimens after all other data have been obtained. When it is desired to determine the susceptibility of alloys to stress corrosion cracking and crevice corrosion, special test specimens should be used which will tend to promote these forms of failure. It will permit also visual examination of coatings, heavier than the film type, to determine their suitability as a protective layer to the underlying metal.

To permit studying the effect of alloy additions on corrosion resistance, nominal per cent composition data are shown in Table 1 for the various alloys which appear in subsequent tables presenting corrosion information. These data have been tabulated in three groups as: Stainless Alloys, Non-Ferrous Alloys and Special High Alloys.

Stainless Type 316 is well known for its ability to resist the corrosiveness of many solutions of varying composition at atmospheric and elevated temperatures required in the production of chemical, petroleum, and pharmaceutical products. Alloy 31 is an alloy that has been known under various designations for many years. Its production has been confined principally to cast parts required for special applications where other similar alloys have an unsatisfactory resistance. In accordance with existing government regulations this alloy would be classified as a stainless steel. As government regulation M-81 limits the addition of molybdenum in stainless type steels to 2.50% maximum, permission must be obtained for the production of equipment or parts in this composition. Alloy 329 has received little attention in the cast form, principally because of limitations in mechanical properties. It has been produced to a limited degree in the wrought form and is probably best known under the trade name Carpenter No. 7 MO. This alloy is currently of interest, as information to be developed may indicate it can be substituted for alloys containing higher percentages of strategically important nickel and molybdenum.

Admiralty metal (inhibited grade) was included for test under the conditions tabulated in Table 2, as it was desired to take advantage of the good heat-transfer property of this alloy. Ampco 18, an aluminum bronze produced by Ampco Metal Inc., is well known for its resistance to many corrosive media. Chemical lead has been widely used for handling hot sulfuric acid solutions below 50% concentration. It is frequently included when tests are conducted in solutions of this acid to obtain comparative data which will permit evaluating the suitability of other alloys tested. Monel metal has been outstanding in its ability to resist the corrosive attack of many nonoxidizing acids and alkalis.

TABLE 2.—CORROSION TEST DATA

Solution Components		Solution Per Cent Composition			
Solution number		I	II	III	IV
(a) Acetic Acid	45-50	45-50	45-50	45-50	33
(b) Methyl Formate, Acetaldehyde, Methyl Acetate, Ethyl Acetate, Acetone, Methyl Alcohol	5	15			
(c) Formic Acid	3	3	4-6		1.5
(d) Methyl Acetate			1		
Temperature °F.	223	223	223	270	
Exposure hours	2,328	2,148	2,544	5,902	
Corrosion Data					
Spec. No.	Alloy	Penetration in./yr.	Penetration in./yr.	Penetration in./yr.	Penetration in./yr.
1	Aloyco 316	0.036	0.013	0.054	0.000
2	Aloyco 31	0.000	0.000	0.007	0.000
3	Admiralty	0.015	0.025	0.006	Completely Corroded
4	Hastelloy C	0.003	0.005	0.005	0.002

Aloyco 20 is a special composition developed a number of years ago for handling principally sulfuric acid. It has since been found a much-needed alloy for handling other corrosive environments. Alloy 35 and 37 are two new compositions which, data developed would indicate, have a resistance to some solution conditions superior to alloys such as Alloyco 20 and Worthite. Worthite is being produced by the Worthington Pump and Machinery Corp. in equipment required to handle many corrosive solutions, principally sulfuric acid. Hastelloy alloys produced by the Haynes Steel Co. have been industrially important because of their superior resistance to process solutions which are extremely corrosive to other commercially available al-

loys. Hastelloy B and C are outstanding for their resistance to solutions containing chlorides or hydrochloric acid. Hastelloy B, C, and D will resist satisfactorily hot intermediate sulfuric acid concentrations which are corrosive to other alloys.

Data presented in Table 2 show both the effect on corrosiveness of minor changes in solution composition and also of relatively minor modifications in alloy compositions. It will be observed the Alloyco 31 composition with only slightly more chromium and molybdenum than Alloyco 316 had a satisfactory resistance to all four solutions, while the Alloyco

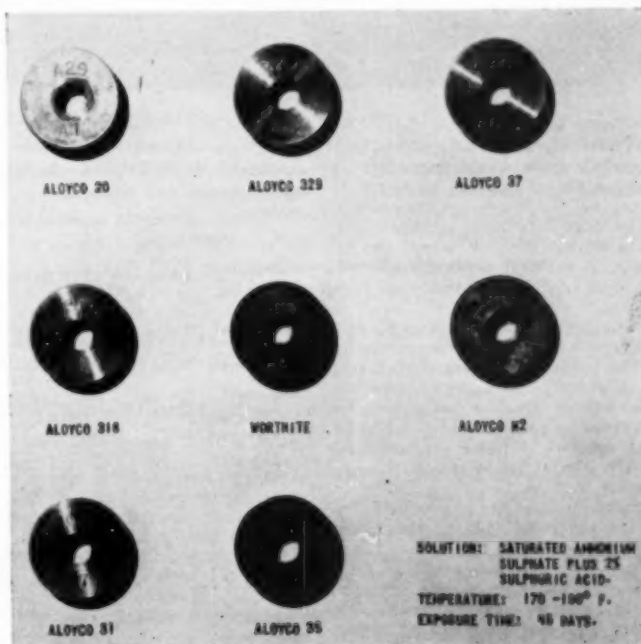


Fig. 3.



316 composition had a satisfactory resistance to conditions of the fourth solution only. The much more highly alloyed Hastelloy C, although quite resistant to all exposures, did not have as good a resistance as Alloyco 31 to three of the conditions.

Data in Table 3 serve to emphasize the importance of having information which shows the effect on corrosion of various compounds present in a solution and, when these data are not available, the value of conducting tests to obtain such information. Laboratory data for exposure No. 1 were developed using a C.P. grade of concentrated sulfuric acid diluted to the proper concentration with distilled water. Data for exposure No. 2 were obtained by exposing an orifice-type corrosion test rod (Fig. 1) within a plant process unit solution line. Comparison of these data would indicate that the organic fatty acids present inhibited

TABLE 3.—CORROSION TEST DATA

Solution:		Laboratory Test	
(1) 10% Sulfuric Acid, no impurities. (No aeration. No agitation.)		Plant Test	
(2) 10% Sulfuric Acid, plus 10% organic fatty acids.		Temperature:	
		(1) 220° F.	
		(2) 212° F.	
Exposure Hours:		(1) 240 (Five 48-hr. exposures. New solution after each exposure.)	
		(2) 672 (Continuous) Penetration	
Alloy		Penetration /Yr.	
		Exposure No. 1 (Laboratory Test)	Exposure No. 2 (Plant Test)
Stainless 316	.....	0.150	0.175
Alloyco 20	.....	0.035	0.014
Alloyco 35	.....	0.076	0.005
Hastelloy B	.....	0.002	0.003
Hastelloy C	.....	0.050	0.011
Monel	.....	0.015	0.006

TABLE 4.—CORROSION TEST DATA

Solution:		Temperature:	
8-15% Nicotine Sulfate		212° F. Max.	
10-20% Nicotine		Exposure Hours: 2,544	
1-10% Sulfuric Acid			
Spec. No.	Alloy	Penetration in./yr.	
1	Alloyco 304	0.244	Specimen surface covered with heavy friable coating. Metal surface beneath coating heavily etched.
2	Alloyco 316	0.002	Same as No. 1, except specimen surface only lightly etched.
3	Alloyco 20	0.000	Specimen surface bright and clean with no evidence of attack.
4	Worthite	0.000	Same as No. 1, except metal surface beneath coating just tarnished.
5	Alloyco 31	0.003	Same as No. 2.

the solution attack on some alloys. This, it will be observed, was appreciable for Alloyco 35 and Monel. As Alloyco 35 must be considered an experimental alloy, principally because wrought products are not available, Monel was selected as the most economical alloy for handling the plant solution of this exposure.

Data presented in Table 4 are not only of value in that they provide information which will permit selecting alloys having a satisfactory corrosion resistance, but also because they show that, under some conditions, an alloy can be found which has excellent corrosion resistance and also will repel the formation of heavy porous coatings.

These coatings are objectionable because they could form a solution cell which would result in accelerated corrosion of the underlying metal. They are also particularly undesirable in equipment which can operate efficiently only when established clearances of moving parts in contact with the solution can be maintained. Alloyco 20, it will be ob-

served, was the only alloy exposed to the conditions of Table 4 which remained bright and clean during the exposure.

TABLE 5.—CORROSION TEST DATA

Solution:		Temperature:	
(a) 0.5-1% $H_2SO_4$ plus small amounts $(NH_4)_2SO_4$ plus unknown contaminant.		(1) 190°-210° F.	
(b) Saturated $(NH_4)_2SO_4$ plus 2% $H_2SO_4$ .		(2) 170°-190° F.	
Exposure Hours:		(a) 1,080	
		(b) 1,080	
Spec. No.	Alloy	Penetration in./yr. (a)	Penetration in./yr. (b)
1	Alloyco 20	0.015	0.000
2	Alloyco 35	0.000	0.000
3	Alloyco 27	0.022	0.000
4	Worthite	0.022	0.000
5	Alloyco 316	0.021	0.000
6	Alloyco 31	0.001	0.000
7	Alloyco 329	0.049	0.000
8	Hastelloy B	0.007	0.019

Data for two plant tests tabulated in Table 5, also show the effect of both solution composition and alloy composition on corrosion rate. Solution (a) a water solution containing a small amount of both sulfuric acid and ammonium sulfate, also had present a small percentage of a constituent which for security reasons could not be made known. Solution (b) although composed of a slightly higher percentage of sulfuric acid and saturated with ammonium sulfate did not have any of the unknown constituent present.

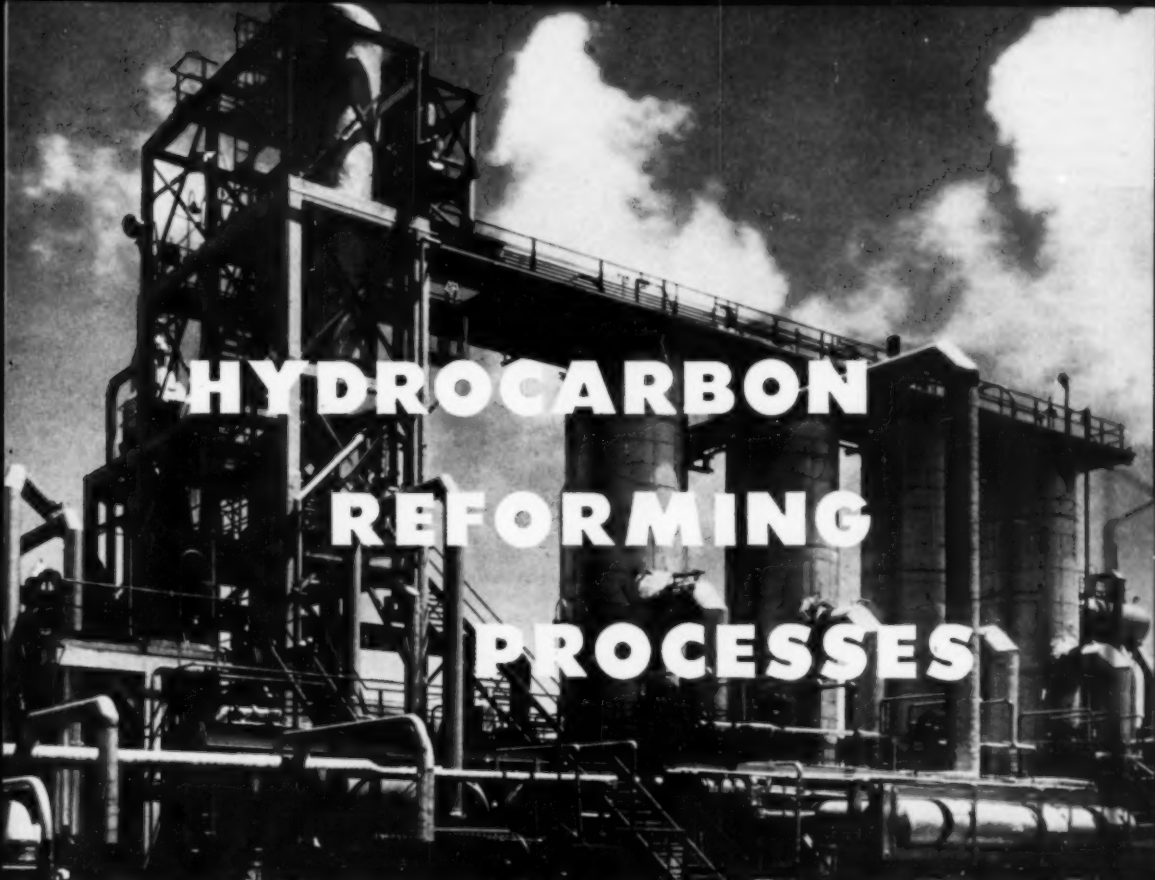
Without additional solution composition information, it would be reasonable to assume that solution (b) would be more corrosive than solution (a). The data obtained however showed the reverse to be true and it therefore appears reasonable to assume that the undisclosed percentage of the unknown contaminant was responsible for this condition.

Corrosion rates tabulated for the various alloys exposed to solution (a) also clearly show the effect of alloy composition or balance on corrosion resistance. Alloyco 35 which has a few per cent less total alloy addition than Alloyco 20 was found totally resistant to the solution conditions. An increase in the percentage of silicon in this alloy, however, to 3% (Alloyco 37) resulted in completely destroying its good resistance. Alloyco 31, which is a slightly richer alloy with respect to chromium and molybdenum than Alloyco 316, was also found to have a good resistance to solution (a). Hastelloy B was the next alloy in order of best resistance and represents the only commercial alloy included in this test that approached showing a satisfactory resistance. As Hastelloy B is best known for its resistance to solutions which are reducing in character, the corrosion rates computed would indicate that solution (a) was somewhat reducing and solution (b) oxidizing. This, it will be noted, was also indicated by the rates computed for the other alloys exposed.

Figures 2 and 3 are photographs showing the surface conditions of specimens, after exposure; data are given in Table 5.

Data presented in these tables serve to show the importance of conducting corrosion tests to determine the most economical alloy for handling corrosive process solutions. They also show the need for research which will lead to the production of new alloys that will have better resistance and broader application than materials now available commercially. Obviously such new alloys will help materially in conserving metals which, because of the present demand, are in short supply.





# HYDROCARBON REFORMING PROCESSES

*In the current chemical revolution, logistics shows competitive organizations all trying to move supplies into the battle area of markets. . . . Aromatics are not chronically in short supply in the U. S.—but within recent years the demands have made aromatics difficult to obtain. . . . Consequently much of our chemical planning has been designed to develop new supply lines. . . . Recently Carbide and Carbon Chemicals Co. announced coal hydrogenation process as one method. . . . Here the petroleum route to aromatics is told by an engineer in a position to know the complete story. . . . The answer to supply will be made on economic considerations solely, but the chemical industry is in for an interesting time in the next few decades as aromatics from coal battle it out with aromatics from petroleum. . . .*

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**T**HE history of the aromatic hydrocarbon chemicals industry in the United States antedates World War I when aromatics such as benzene, toluene, and xylene were recovered as by-products of the coal-tar industry and the principal field of consumption was in the manufacture of dyes for the textile industry. As early as 1900, some crude naphthalene was recovered from crude coal tar.

However, it was not until the outbreak of World War I, when our supplies of dyestuff and fine organic chemicals from Germany were cut off, that the United States began to produce sizable quantities of aromatics. From 1915 to 1918, production of coal-tar light oil, from which aromatics are recovered, increased from 20 to 65 million gallons per year. However, even this enormous expansion could not satisfy the demand for toluene

required for the explosive trinitrotoluene. In addition to stripping toluene from illuminating gas, commercial production of toluene from petroleum by the thermal decomposition of the non-aromatic components of toluene-containing virgin naphthas was undertaken.

After World War I, production of toluene, which had been used almost exclusively for TNT manufacture, dropped almost to nothing and since

production from petroleum proved to be uneconomic compared with coal-tar toluene, the practice was discontinued.

**Importance of Coal Tar.** In the period between wars, the aromatic hydrocarbon chemical industry reverted to coal tar as the principal raw material and no significant commercial production of pure aromatics from petroleum was evident. The increase in demand featured a steady growth which essentially disregarded changes in the business cycle and continued throughout the years up to World War II. In all this period, there was never a real shortage of the major refined products from coal-tar sources due to the fact that from 5 to 15 million gallons per year of aromatic hydrocarbon concentrates were supplied by the petroleum industry. These concentrates were made mostly by solvent extraction, although one plant did use the so-called hydrogenation process. The basic aromatic hydrocarbons, benzene, toluene, xylene, and naphthalene, were, up until 1940, generally in ample supply. As late as the year just mentioned, only about 40 million gallons of refined benzene were recovered from an estimated potential from coal tar of 135 million gallons, with the remainder utilized in a partially refined state to mix with gasoline for use as a motor fuel. Toluene production, with a potential supply of approximately 35 million gallons from coal tar reached only 20 million gallons by 1939 and was used principally as a solvent rather than for chemical manufacture. Xylene production reached only 5 million gallons by 1940, all from coal tar, and was used as a solvent and in gasoline blends. Naphthalene production, with a potential of around 350 million pounds per year, reached only about 160 million pounds in 1940.

Before World War II, therefore, there was little incentive or need for the commercial production of these aromatics from petroleum since abundant

supplies at a relatively low price were available from the coal-tar chemical industry. However, a great deal of development work on aromatics from petroleum was carried out in the United States during these twenty years of comparative peace. Of greatest importance were the discovery and development of the hydroforming process, which was developed primarily for the improvement of octane in motor fuels.

At the start of World War II, the demand for toluene for use in TNT again greatly exceeded the supply available from coke-oven sources, and the hydroforming process was projected immediately into plants to produce toluene. Since the hydroforming process is basic to the petroleum industry's current position as an important supplier of aromatic chemicals, a rather detailed description of this process is pertinent to this discussion.

**Hydroforming Process.** This process consists of the high temperature and pressure catalytic treatment of naphthas in the presence of hydrogen to dehydrogenate cyclohexane, methylcyclohexane, dimethylcyclohexane, etc., to the corresponding benzene derivatives. Depending upon the composition of naphtha cut, benzene, toluene, or xylene can be produced according to the principal reactions shown in Fig. 1.

Although these reactions represent the principal mechanism for aromatics formation by hydroforming, a number of side reactions also are stated to take place as follows:

1. Aromatization of paraffins, for example, conversion of normal heptane to toluene.
2. Isomerization of naphthenes or paraffins.
3. Various thermal decompositions.
4. Alkylation and condensation reactions to form small quantities of high boiling material.
5. Decomposition of sulfur-containing compounds.
6. Hydrogenation of olefins.

Hydroforming is a cyclic operation requiring periodic regeneration of the catalyst by oxidation to remove the carbon produced in the reaction and deposited on the catalyst as coke and to balance heat requirement. The cyclic nature of hydroforming is a definite limitation of the process compared to the new catalytic reforming processes developed since the war.

Since the absence of olefins reduces coke formation, the immediate conversion of olefins to the corresponding paraffin due to the high partial pressure of hydrogen, permits the process to be operated on stream for several hours—depending upon plant design and operating conditions—before catalyst regeneration.

The hydroformer uses a coprecipitated molybdena-alumina dehydrogenation catalyst having a useful life of from one to more than two years.

Since the main reaction is highly endothermic, two or more reactors are generally used in series in order to introduce the required amount of heat at the proper temperature level. Although the reaction can be carried out at pressures varying from 3 to 25 atm., the usual operating pressure is about 15 atm., and the partial pressure of hydrogen from 40 to 90%. The usual temperature range is 900-1000° F.

Although all the hydrogen is obtained from the gases liberated in the process, it is important to note that hydroforming represents a dehydrogenation process in the presence of excess hydrogen over that produced in the dehydrogenation reaction. This excess is provided by a recycle of the hydrogen-rich light gas (about 70%  $H_2$ ) produced in the process.

**Hydroforming and Toluene.** Although, as just mentioned, the hydroforming process was developed primarily to improve octane, it can readily be seen that, by careful selection of feedstock and minor changes in operating conditions, this process can be directed toward the production of benzene, toluene, or xylene. Since toluene was a critical product during World War II, ten hydroforming plants were built to produce toluene. Steps involved in the production of toluene by hydroforming were generally about as follows:

1. Preparation of a 200-250° F. boiling-range naphtha from a highly naphthenic crude. This cut should contain the maximum content of methylcyclohexane and toluene. In actual practice, the crude naphtha cut points at the primary distillation units were usually adjusted for the recovery of about 90-95% of the methylcyclohexane in the crude.
2. Hydroforming this cut to give maximum toluene yield—For the maximum production of toluene, the hydroformer is operated at a pressure of 10 atm.

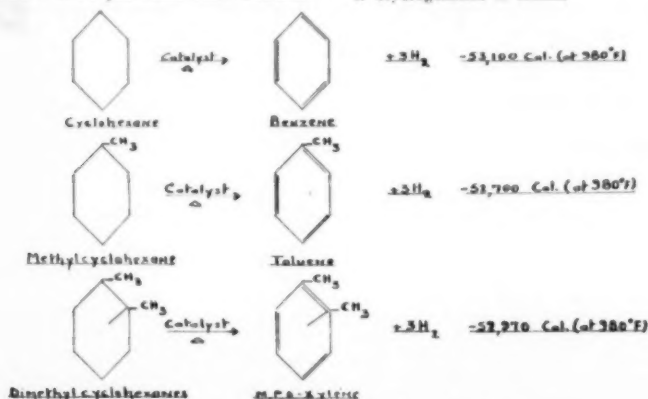


Fig. 1. Principal reactions for aromatics production from hydroforming process.

and a temperature of about 950° F. From a highly naphthenic 200-250° F. virgin naphtha which contained 33.6 vol. % methylcyclohexane and 0% toluene, yields of 28 vol. % based on feed were realized during the war.

3. Preparation of a "heart cut" from this "hydroformate" after preliminary stabilization. This is accomplished by distillation in two columns or if, in addition to the heart cut, a normal heptane stream is produced, three columns are used. In some operations an additional 200° F. end point light aviation cut is also produced requiring a fourth column. The heavy aromatic product is usually rerun to recover xylenes.

4. The isolation of pure toluene from this heart cut. This concentration can be accomplished in a number of ways, such as the azeotropic distillation with methyl ethyl ketone-water azeotrope, solvent extraction with liquid sulfur dioxide, or phenol extractive distillation. Extraction of toluene with liquid sulfur dioxide results in an extract phase containing 65-70% aromatics. Additional purification of this extract is needed for nitration grade toluene.

A method of obtaining nitration grade toluene without using these special distillation methods was used successfully by the Standard Oil Company of California during the last war by utilizing the hydroforming process to destroy all nonaromatic hydrocarbons boiling close to toluene. A 180-230° F. boiling point fraction of California crude, selected to include the dimethyl pentanes at the lower ends but to exclude large concentrations of nonaromatics boiling near toluene at the upper end, was charged to the hydroformer operating at a pressure of 13 atm. and a temperature around 1000° F. The product was separated into a fraction boiling from 180-220° F., which was recycled with fresh feed, and a fraction boiling from 220° F. to 230° F. containing 90% toluene. This second fraction was reprocessed over the catalyst to increase the toluene concentration from 90% to 99%. After reprocessing, the product was topped, acid-treated and rerun to produce nitration grade toluene.

In addition to that supplied by the hydroforming process, appreciable quantities of toluene were produced by the Shell Oil Co. with its own two-stage process. In the first stage, dimethylcyclopentane was catalytically isomerized to methylcyclohexane thereby increasing the volume of material susceptible to dehydrogenation. In the second stage the isomerization product, plus additional methylcyclohexane, was catalytically dehydrogenated to toluene.

The hydroforming process also enabled the petroleum industry to provide the large quantities of xylenes required for octane improvement of aviation gasoline during the last war. In 1945 some 46 million gallons of xylenes were reported as produced from petroleum (vs. 10 million from coal tar) even though the major portion of the xylenes pro-

duced were consumed as a constituent of gasoline and would not show up in the statistics.

As just mentioned, xylenes are also produced when operating the hydroformer for maximum toluene production. However, by selection of a narrow cut of  $C_8$  naphthenes as feedstock, the hydroformer can be operated to produce primarily *o*-, *m*-, and *p*-xylenes and ethyl benzene. For this operation a virgin naphthenic fraction with a boiling range of 230-260° F. is charged to the hydroformer at 900-1000° F. under pressures ranging from 3 to 25 atm. The product contains a mixture of ethyl benzene and the three xylenes at relatively high concentrations.

**Toluene and Xylene from Petroleum.** Although benzene requirements during World War II increased rapidly (from 140 million gallons in 1940 to 210 million gallons in 1944), because of increased demand for phenol and styrene for synthetic rubber, the supply did not become as critical as in the case of toluene. For this reason, and also because of the high cost of synthetic benzene, the commercial development of benzene from petroleum (i.e., from the hydroformers) did not approach that of toluene's.

Naphthalene production, all from coal-tar sources, was approximately doubled from 1940 to 1943 in order to supply the increased demands for the manufacture of phthalic anhydride and beta-naphthol.

Summarizing developments during the late war, this period saw the first large-scale production of toluene and xylene from petroleum but no significant production of benzene or naphthalene from petroleum.

With the end of hostilities, the hydroforming plants reverted to their expected peacetime function of supplying gasoline. As expected, the demand for toluene dropped sharply, relieving the need for hydroformers in this use. Benzene demand, however, continued to rise as deferred peacetime demand more than made up for the drop in use in synthetic rubber. The rapid growth of the plastics industry requiring increased quantities of phenol and polystyrene, plus the phenomenal growth of the synthetic detergent industry, soon brought about a shortage of benzene, even though steel operations continued throughout the postwar period at an unusually high level. The extent of this shortage, which has been increased by the demands of the mobilization economy, is illustrated by the forecasted requirements, estimated by representatives of the benzene-consuming industries in the United States. These estimates which have been made for both a mobilization and normal economy are shown in millions of gallons. (See Table I.)

TABLE I.—ESTIMATED REQUIREMENTS OF BENZENE

Year	Mobilization	Normal
1951	252	222
1952	307	243
1953	338	262
1954	379	289
1955	411	315

Since the current coke-oven benzene production rate of 180 million gallons per year is close to the estimated maximum potential of 190 million gallons per year, and the imports of 55-60 million gallons per year are considered the maximum available, it is apparent that a new source of supply—petroleum—is needed to meet the incremental demands.

At present benzene is being derived from petroleum by adaptations of the processes which were used successfully during the late war for toluene manufacture and in the postwar period for upgrading aviation gasoline. Benzene production from these sources, during 1951, is estimated to be about 20 million gallons. Operation for benzene production using the hydroforming process is similar to that described earlier for toluene but charging a narrow cut naphthenic fraction containing maximum cyclohexane as feedstock. Similarly, it is reported that Shell is now using its two-stage isomerization and dehydrogenation process, which produced toluene during World War II, for benzene production. In the current operation, methylcyclopentane derived from natural or straight-run gasoline is catalytically isomerized to cyclohexane in the first stage. The isomerization product plus additional cyclohexanes are then dehydrogenated over a second catalyst to benzene in the second stage.

**Platforming Process.** Recently, new catalytic-reforming processes which permit production of aromatics or high-octane gasoline at high yields in a continuous operation requiring no regeneration, or infrequent regeneration if operated at severe conditions, have been developed and are assuming the major position in the production of aromatics from petroleum. One of these processes, called Platforming, has been accepted by most of the industry to meet the need for additional aromatics, especially benzene. Platforming, developed by Universal Oil Products Co., was first used commercially in 1949 for upgrading gasoline. The process uses a catalyst containing platinum and is essentially continuous, since periodic regeneration of the catalyst is not necessary. An advantage of the Platforming process is that it has been found suitable for the conversion of  $C_8$  ring naphthenes, by isomerization, as well as  $C_6$  ring naphthenes, to benzene. Moreover, during the formation of benzene, the paraffinic constituents undergo isomerization. The high extent of branching in the product

makes the residual paraffinic material valuable from a motor fuel standpoint. The comparative ease with which the process can be switched to either aromatics or motor fuels by modification of feedstock and operating conditions is also an important factor in the economics of the Platforming process.

Production of benzene by Platforming is accomplished by charging a fraction, from a highly naphthenic crude, containing large percentages of methylcyclopentane and cyclohexane. The feed is passed through reactors, usually four in series, filled with a supported platinum-base catalyst in the form of  $\frac{1}{4}$ -in. pellets. The principal reaction is dehydrogenation, and the yield of benzene from  $C_6$  naphthenes in a single pass is 80% of the theoretical and may be increased by recycling. Natural benzene present in the feed (normally 1-9% in a typical 140-185° F. fraction) passes through the reactors unchanged. Reactor temperatures of about 900° F. and pressures around 250 lbs./sq.in. are maintained. Following the dehydrogenation section, the aromatic rich stream is charged to a stabilizer, then to a separator to remove paraffins, and finally to the fractionation section to recover benzene, toluene, and xylene. The paraffins removed in the separator have been isomerized under the conditions used for benzene production and are therefore important constituents of high octane motor fuel.

At present there are twenty-one Platformers either in operation, under construction, or in the planning stage. However, of these, only six are being designed and constructed to recover aromatics for chemical use. When in operation in mid-1953, these plants alone will produce about 55 million gallons of benzene per year. However, in evaluating the potential supply situation regarding benzene—toluene and xylene too—the flexibility of the Platforming process must be recognized. This flexibility makes all twenty-one Platformers potential aromatics producers.

**Platinum Catalyst.** Although the majority of new production of benzene and other aromatics from petroleum will utilize the Platforming process, there are at least two other processes, aside from hydroforming, which will also be used. These processes are based also on catalytic reforming of naphthene fractions. One of these, developed by Atlantic Refining Co., is similar to the Platforming process and uses a new platinum catalyst developed by Atlantic and manufactured by Davison Chemical Co. Atlantic has announced plans to construct a plant at Philadelphia to produce seven million gallons per year of benzene using this process.

**Houdriforming.** Another process recently announced is Houdriforming,

developed by Houdry Process Co. Houdriforming is a continuous catalytic reforming process which reportedly produces good yields of benzene, toluene or xylenes from close-cut naphtha fractions. It is claimed that conversions of naphthenes to aromatics up to 95% of equilibrium are obtained with this process. A Houdriformer is being constructed by the Sun Oil Co. to produce thirteen million gallons per year of benzene.

Although not specifically designed for benzene production, the three new units planned by Socony-Vacuum using its own TCR (Thermofor Catalytic Reforming) process are also potential producers of benzene.

A tally of the expected production of benzene from petroleum by all methods indicates that about 100 million gallons per year will be available from this source by the end of 1953. Assuming that coke-oven benzene will operate near its estimated capacity of 190 million gallons per year and imports will continue at the high rate of about 55 million gallons, the additional benzene from petroleum will give a supply rate of approximately 345 million gallons by the end of 1953. Since mobilization requirements for the year 1953 are estimated at 338 million gallons per year, there would appear to be a reasonably close balance between supply and demand for that year provided there are no serious construction delays in the new benzene plants.

The demand for toluene in the United States is closely related to the defense effort, particularly TNT and aviation fuel. Relatively little progress has been made in the development of chemical derivatives of toluene. A possible exception is the use of vinyl toluene as a substitute for styrene both in synthetic rubber and in paints and varnishes. Although experimental commercial manufacture of synthetic rubber based on vinyl toluene has been started by Good-year, and is reported to be satisfactory, the requirements for toluene are expected to be small compared with the quantities potentially recoverable from these new catalytic reforming units and hydroformers. It is expected that most of the toluene produced will continue to be used for blending into aviation fuels.

Although a large part of the increased quantities of  $C_6$  aromatics available from these new plants will, like toluene, be consumed in gasoline blends, the outlook for increased consumption of the xylenes as chemical intermediates is considerably more promising than in the case of toluene. Phthalic anhydride, which was once produced exclusively from naphthalene, has also been derived commercially by the oxidation of orthoxylene since 1945. The separation of the ortho-isomer from the mixed xylene to obtain

the raw material for phthalic anhydride manufacture also gives increased value to the meta-para mixture in aviation gasoline blends, since the orthoisomer is detrimental in this use. A rapidly expanding use for para-xylene is in the manufacture of terephthalic acid which is used for the new polyester fiber Dacron and a new transparent base for film (Mylar). The meta-isomer is of importance as an aviation gasoline component, and although its commercial use as a chemical intermediate is limited currently to dyestuff and musk intermediates, development work indicates that its production cost can be lowered for use in the manufacture of isophthalic acid—a promising new compound for alkyd and polyester resins and plasticizers. In view of the rapid progress already made and the attractive possibilities now in the process of development for the use of individual xylene isomers as chemical intermediates, together with the established uses of xylol as a solvent and in gasoline blends, it is anticipated that the increased volumes of xylenes made available from the new aromatics plants will be readily absorbed by the markets.

While they are not present in substantial proportion in coke by-product fractions, alkyl benzenes higher than the xylenes are found in hydroformer and Platformer streams in substantial quantities: *Pseudocumene* (1, 2, 4 trimethyl), *mesitylene* (1, 3, 5 trimethyl), *durane* (1, 2, 4, 5 tetramethyl) and *isodurane* (1, 2, 3, 5 tetramethyl) are the principal products of interest in this connection. None of these is currently manufactured commercially from catalytic reformer streams. However, it is probably safe to say that the basic technology for the commercial recovery of these compounds has been worked out and that in due time their manufacture on a substantial scale will develop.

Naphthalene has been in short supply for some time. However, according to Government reports, recently issued, the shortage of this commodity is expected to be relieved by about 1954 through improvements in existing recovery operations and expanded coking and by-product recovery capacity. Even so, the petroleum industry stands ready to provide *o*-xylene as a functional substitute for naphthalene in the manufacture of its principal derivative, phthalic anhydride.

In summary, it is apparent that the petroleum industry is rapidly assuming a dominant position in the manufacture of benzene and its homologues. The nation and the chemical and petroleum industries can be proud of the speed and smoothness with which the threatened major shortages of these all-important materials have been overcome.

# PIPE-LINE DESIGN

## For Non-Newtonian Solutions and Suspensions

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THE transport of solid-in-liquid suspensions and solutions in pipe lines is a very common occurrence in the chemical industry. A large fraction of such materials are non-Newtonian in character; that is, they do not have a constant viscosity at a given temperature and concentration, but instead exhibit a variable viscosity dependent upon the pipe diameter and liquid velocity plus certain other factors. For these cases, therefore, the customary methods for determining the viscosity are not applicable and the customary methods of pipe-line design cannot be employed without modification. The flow properties of these materials usually have to be determined experimentally before a satisfactory pipe-line transport system can be designed.

It is the purpose of this paper to show how the flow properties of non-Newtonian suspensions and solutions can be evaluated in rotational-type viscometers and pipe-line-type viscometers and how these flow-property data can be processed and scaled up to provide the basis for design of plant-scale pipe lines. Experimental data were obtained on two representative suspensions and on two solutions and are presented to illustrate this correlation between rotational- and pipe-line-viscometer data and to prove the validity of the scale up. It is not the purpose of this paper to present viscosity data on any particular material or class of materials, for such information is of little value, particularly in the case of suspensions where particle size and shape and degree of dispersion are important factors that generally cannot be reproduced.

### Classification of Non-Newtonian Materials

Solids-in-liquids suspensions and solutions are classified according to the gen-

The design of pipe lines for the flow of non-Newtonian solutions and suspensions requires methods for evaluating viscosity and for computing pressure drop different from those customarily used in the case of simple Newtonian fluids. Information is presented on the various classifications of non-Newtonian fluids and on the methods of obtaining their shear diagrams using rotational or pipe-line-type viscometers. Methods are presented whereby data given by either type of viscometer can be converted to a form directly useful in the design of plant-scale pipe lines. Corroborative experimental data are presented on four representative materials. A design procedure is given to outline the steps to be taken in sizing a pipe line or computing pressure drop. The paper is concluded with some general remarks on the selection of pumps for this service.

eral type of functional dependence of the shear stress on the rate of shear, that is, according to the general shape of the shear diagram or plot of rate of shear vs. shear stress. There are two main classifications, Newtonian and non-Newtonian. The Newtonian fluids are characterized by a constant viscosity, independent of the rate of shear. A typical shear diagram for such a material is given by curve *A* in Figure 1. The viscosity in this case is given by the inverse slope as follows,

$$\mu = \eta \tau / (-dV_r/dr). \quad (1)$$

Non-Newtonian fluids on the other hand exhibit a variable viscosity dependent upon the rate of shear and in some cases

upon the duration of shear. These materials are subdivided into five general types: (1) Bingham plastic, (2) pseudoplastic, (3) dilatant, (4) thixotropic, and (5) rheopectic.

1. A typical shear diagram for a Bingham plastic is shown in curve *B*, Figure 1. The intercept is called the yield stress,  $\tau_0$ . The inverse slope of the line is the coefficient of rigidity,  $\eta_0$ , divided by the conversion factor,  $g_0$ . Some examples of Bingham plastics are sewage sludge (5) and grain suspensions (3) in water.
2. A typical shear diagram for a pseudoplastic is given by curve *C*, Figure 1. The inverse slope of the asymptotic straight line multiplied by the conversion factor,  $g_0$ , is called the limiting viscosity at infinite shear,  $\mu_\infty$ . Similarly, the inverse slope of the tangent

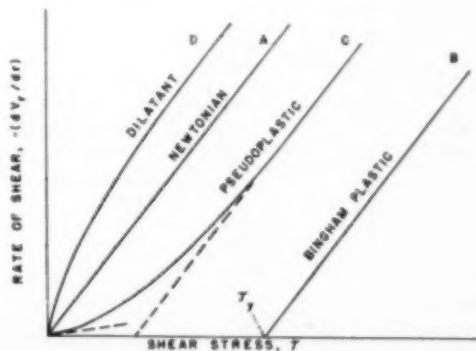


Fig. 1. Representative fundamental shear diagrams for Newtonian, Bingham-plastic, pseudoplastic, and dilatant materials.

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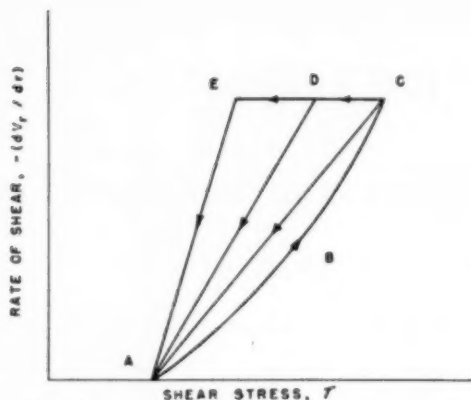


Fig. 2. Representative fundamental shear diagram for thixotropic material.

at zero rate of shear multiplied by the conversion factor,  $g_{cs}$ , is called the viscosity at zero rate of shear,  $\mu_0$ . An explanation of pseudoplasticity has been given by Green and Weltmann (1). Two examples of pseudoplastics are Napalm and cellulose acetate in acetone. Napalm is a colloidal solution of the aluminum salts of oleic, naphthenic, and coconut-oil fatty acids in gasoline. Further details on Napalm can be obtained (2 and 6).

3. A typical shear diagram for a dilatant material is given by curve  $D$ , Figure 1. A theory for dilatancy has been advanced by Reynolds (21, 1, II). Some examples of dilatant materials are starch suspensions in water, mica suspensions in water, quicksand, and beach sand.
4. Thixotropic fluids possess a structure the breakdown of which is a function of time as well as of rate of shear. This structure can rebuild itself if not prevented from doing so by externally applied forces. Many theories and explanations have been advanced for thixotropy (11, 12, 14, 18, 22, 24). A typical shear diagram for a thixotropic material as obtained with a rotational viscometer is shown in Figure 2. The area within the loop is an indication of the amount of thixotropy, a large loop indicating considerable thixotropy (1, 8, 9, 10) and no

loop indicating a simple Bingham plastic. If the rate of shear is held constant after point  $C$  is reached on the up curve, the shear stress will decrease along the path  $CD$  until point  $E$  is reached, beyond which no further breakdown can occur at that particular rate of shear. If the rate of shear is then decreased, the down-curve  $EA$  is then followed. Any number of intermediate down-curves, such as  $DA$ , are possible. Some examples of thixotropic fluids and suspensions are milk, mayonnaise, greases, drilling muds, paints, inks, and gypsum in water.

5. Rheopectic materials are those which will set up or build up (increase in apparent viscosity) very rapidly upon being rhythmically shaken or tapped. Some examples of rheopectic materials are gypsum suspensions in water, bentonite sols, and vanadium pentoxide sols.

Most solutions and suspensions are Newtonian at low concentrations, changing to one of the non-Newtonian classifications when a certain critical concentration is reached. In the case of suspensions, this critical concentration depends upon particle size and shape and upon degree of dispersion as well as upon con-

centration. Further increases in concentration have been found in many cases to result in still further changes in classification.

### Viscous Flow

**Pipe Lines.** For the case of viscous flow of Newtonian fluids through pipe lines, the pressure drop due to friction is given by the familiar Poiseuille's equation,

$$\Delta p = 32\mu LV/g_c D^3 \quad (2)$$

In the case of non-Newtonian solutions and suspensions, the same equation may be used by replacing the viscosity term,  $\mu$ , by an apparent viscosity term,  $\mu_a$ . The problem of determining the proper value of  $\mu_a$  to be used, however, is frequently a difficult one since it is not a constant, as discussed earlier.

The mathematical analysis of the viscous flow of a Bingham plastic in a circular pipe was presented by Bingham (4, 5). The results of the analysis are as follows:

$$8L/g_c D = (1/\eta)(\tau_w - 4\tau_0/3) \quad (3)$$

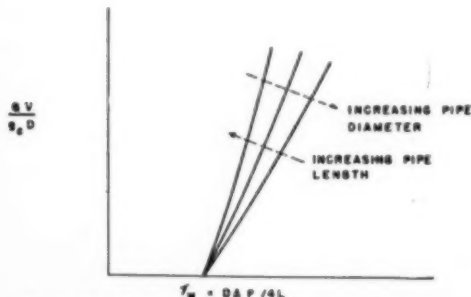


Fig. 4. Effect of pipe dimensions on shear diagram of thixotropic material.

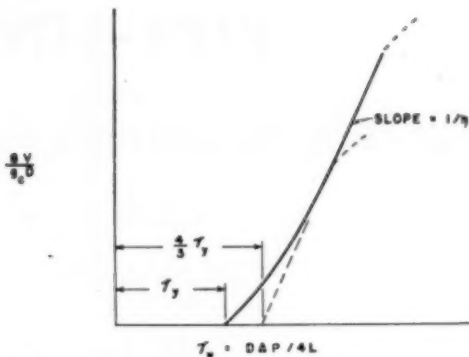


Fig. 3. Shear diagram for Bingham-plastic flow in cylindrical pipe.

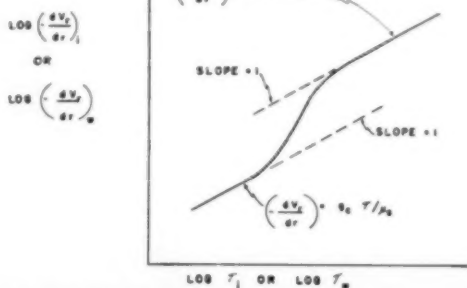


Fig. 5. Representative combined shear diagram for pseudoplastic material.



and

$$\mu_s = (g_c \tau_p D / 6V) + \eta \quad (4)$$

A typical diagram for the viscous flow of a Bingham plastic in a circular pipe is given in Figure 3. The equation of the asymptote is given by Equation (3), and the inverse slope of the asymptote is the coefficient of rigidity,  $\eta$ . The yield stress is  $\tau_p$ , and the intercept of the asymptote is  $4/3 \tau_p$ .

A shear diagram of the type shown in Figure 3 can be obtained in any size pipe ranging from capillaries to plant-scale pipe lines (3, 5). The apparatus known as a pipe-line viscometer consists of a known length of pipe with either a blow case or a pump to force the material through the pipe. The pressure drop is measured for various rates of flow. It is advisable to use more than one pipe size to determine scale-up factors, if any, and also to determine whether thixotropy exists. If the suspension is thixotropic, the use of a blow case is preferable to a pump since the latter will break down the fluid before it flows through the pipe. The presence of thixotropy is indicated when separate curves are obtained for different pipe sizes and lengths, as shown in Figure 4. More breakdown and thus lower viscosities are obtained with longer lengths and smaller diameters.

A plant-scale pipe line can readily be sized once the shear diagram is obtained from the pipe-line viscometer data, provided the material is not thixotropic. If it is thixotropic, extrapolation is generally required, which introduces uncertainties. Trial and error is involved since the diameter term appears in both the ordinate and abscissa, and velocity is a function of diameter. The latter can be avoided by plotting  $8q/\pi D^3$  as ordinate on the shear diagram in place of  $8V/g_c D$ . The Reynolds number for the design case should finally be checked to see whether the flow will still be viscous. If the Reynolds number exceeds 2100, the procedure for turbulent flow has to be consulted. The Reynolds number is given by

$$N_{Re} = D V \rho_m / \mu_s \quad (5)$$

A mathematical theory for pseudo-plastic viscous flow has been presented by Williamson (27, 28); however, the foregoing method of obtaining and applying pipe-line-viscometer data is also applicable in this case.

**Rotational Viscometers.** Rotational viscometers consist of two concentric cylinders, outer or "cup" and inner or "spindle." There are two types: 1) rotating spindle and stationary cup, e.g., Brookfield and Stormer; and 2) rotating

cup and stationary spindle, e.g., MacMichael and Precision-Interchemical.

Rotational viscometers are not suitable for evaluating flow properties of suspensions that settle rapidly, since the particles can settle out and also can be thrown away from the rotating cylinder owing to centrifugal force.

For a Bingham plastic, a shear diagram can be obtained by plotting simply the rate of rotation,  $\omega$ , vs. torque,  $T$ . A diagram similar to that shown in Figure 1, curve B, is obtained. The straight line obtained can be analyzed by the use of the Reiner-Riwlin (20, 7) equation as follows,

$$\omega = (g_c T / 4\pi h \eta) [(1/r_s^2) - (1/r_o^2)] - (g_c \tau_p / \eta) \log_e (r_o/r_s) \quad (6)$$

$$\eta = 9.55 g_c (T - T_y) B_1 / \omega' \quad (7)$$

where

$$B_1 = [(1/r_s^2) - (1/r_o^2)] / 4\pi h \quad (8)$$

$$\tau_y = T_y B_2 \quad (9)$$

where

$$B_2 = [(1/r_s^2) - (1/r_o^2)] / [4\pi h \log_e (r_o/r_s)] = B_1 \log_e (r_o/r_s) \quad (10)$$

The apparent viscosity for pipe-line flow can then be calculated by evaluating  $\eta$  and  $\tau_y$  from Equations (7) and (9) and substituting into Equation (4). The down curve for a thixotropic material and the straight portion of a pseudo-plastic curve can both be treated in the same manner. In the latter case, the  $T_y$  is obtained from the intercept of the asymptote.

A more general method is available for comparing rotational viscometer results with pipe-line viscometer results and in converting from one to the other. In the case of the rotational viscometer, it involves the determination of the rate of shear and shear stress at the inner cylinder wall. The latter can be calculated directly from the torque readings as follows,

$$\tau_i = T / (2\pi h r_i^2) \quad (11)$$

The rate of shear is computed as follows. The general equation for rotational viscometers consisting of concentric cylinders is

$$2(d\omega/dr)_i = (g_c/\mu_i) [1 - (r_i/r_o)^2 (\mu_i/\mu_o)] \quad (12)$$

Assuming that the viscosity is an inverse power function of the shear stress and incorporating Equation (1) into Equation (12),

$$-(dV/dr)_i = 2\tau_i (d\omega/dr)_i / [1 - (r_i/r_o)^{2n}] \quad (13)$$

where

$$n = d \log \omega / d \log \tau_i \quad (14)$$

The exponent  $n$  is thus the slope of the log-log plot of  $\omega$  vs.  $\tau_i$ . The slope  $d\omega/dr_i$  is taken from a curve of  $\omega$  vs.  $\tau_i$  at the point in question. Many slurries and solutions met in practice do give constant values of  $n$  over most of the viscometer range. However, if  $n$  is not constant, an approximation can be obtained by evaluating it at the value of  $\tau_i$  in question.

**MacMichael Viscometer** (Eimer and Amend). This viscometer is well adapted to the study of non-Newtonian materials. The torque is computed simply from the following equation,

$$T = K \theta_s \quad (15)$$

and the shear stress and rate of shear at the inner wall are obtained from Equations (11) to (14).

**Precision-Interchemical Viscometer** (Precision Scientific Co.). This instrument (7, 25) is well adapted to the study of non-Newtonian materials including those exhibiting thixotropy. Equations (11) to (14) also apply for this viscometer.

**Brookfield Synchro-lectric Viscometer** (Brookfield Engineering Laboratories). A calibration is given for each spindle in terms of the viscosity of a Newtonian material that would give the same scale reading. The corresponding torque is given by

$$T = 4\pi \mu_s \omega r_i^2 h / g_c \quad (16)$$

The shear stress and rate of shear at the spindle wall are obtained by use of Equations (11) to (13), noting that  $(r_i/r_o) = 0$ .

**Stormer Viscometer** (Arthur H. Thomas Co.). The torque corresponding to any given weight is given by the product of the weight and the radius of the pulley. Equations (11) to (14) can then be used to obtain the shear stress and rate of shear at the inner cylinder wall. The instrument can be used to study non-Newtonian materials which do not involve a time-dependent phenomenon such as thixotropy.

**Pipe-line and Rotational-viscometer Comparison.** A comparison of pipe-line- and rotational-viscometer data can be made on the basis of comparing the rate of shear and shear stress at the pipe wall with the rate of shear and shear stress at the inner cylinder wall of the rotational viscometer. In the preceding section on rotational viscometers, it has been shown how a plot of rate of shear vs. shear stress at the inner cylinder wall can be prepared from a plot of torque vs. angular velocity. In the case of the pipe line, a plot of  $8q/\pi D^3$  vs.  $D\Delta p/4L$  is prepared first. The latter term is the shear stress at the pipe wall. The rate of shear at the pipe wall is more difficult to evaluate. Rabinowitsch (19) presented an expression for this in 1929 which is independent of the shape of the flow diagram. The significance of the expression was not fully realized at the time, and later Mooney (25) in 1931

showed how the expression could be applied to pipe-line data. The expression is

$$-(dv_r/dr)_w = 3(8q/\pi D^3) + (D\Delta p/4L) \left[ d(8q/\pi D^3)/d(D\Delta p/4L) \right] \quad (17)$$

As can be seen, the rate of shear at the pipe wall,  $-(dv_r/dr)_w$ , can be obtained from Equation (17) together with the aforementioned plot of  $8q/\pi D^3$  vs.  $D\Delta p/4L$ , where values of the ordinate and the slope can be obtained for selected values of  $D\Delta p/4L$ .

Both pipe-line and rotational-viscometer data for a given material should fall on a single common curve when correlated in this manner, provided that there is no time dependency involved such as thixotropy or rheopexy. Figure 5 shows the type of plot that results from the foregoing correlation for a pseudoplastic material. The lower portion of the curve approaches an asymptote, which means that at low rates of shear the apparent viscosity is a constant,  $\mu_s$ . Viscous flow in large pipes (generally 2 in. or larger in diameter) usually falls in this region. The central curved portion is the region where the rotational-viscometer and small-pipe-

line data generally fall. The upper portion of the curve approaches another asymptote, which means that at high rates of flow, within the limits of viscous flow, the apparent viscosity is a constant,  $\mu_\infty$ . Data from very small pipes and from capillary tubes generally fall in this region.

The foregoing method of comparing pipe-line and rotational-viscometer data is convenient for designing plant-scale pipe lines for the viscous flow of non-Newtonian fluids involving no time dependency. Rotational-viscometer data can be obtained with the material in question and the shear diagram,  $-(dv_r/dr)_i$  vs.  $\tau_i$ , prepared. Two methods are available to convert this to the customary pipe-flow diagram. The first and probably the simplest method is to fit an equation to this rotational-viscometer shear diagram. If a single equation is not adequate, the curve can be broken in segments and an equation assigned to each segment.

$$-(dv_r/dr)_i = \phi(\tau_i) = \psi(D\Delta p/4L) \quad (18)$$

Frequently equations of the parabolic type will fit. Equation (18) can then be substituted into Equation (17) to give

$$\psi(D\Delta p/4L) = 3(8q/\pi D^3) + (D\Delta p/4L) \left[ d(8q/\pi D^3)/d(D\Delta p/4L) \right] \quad (19)$$

Equation (19) can then be formally integrated to give the equation of the pipe-flow diagram,  $8q/\pi D^3$  vs.  $D\Delta p/4L$ , or segments thereof. The required pipe diameter can then be obtained from this diagram for a given pressure drop or the pressure drop for a given pipe diameter.

The second method involves a graphical integration using the following double-integral equation:

$$q = 2\pi \int_0^R \int_0^r \phi(\tau_r) dr \cdot r dr \quad (20)$$

The foregoing procedure has not been previously described, to our knowledge, in engineering literature. It has been used with success by the authors on industrial problems for the past eight years. Experimental data are presented later in the paper on two non-Newtonian suspensions and two non-Newtonian solutions to demonstrate the validity of the procedure. However, it has recently come to our attention that Equation (17) was given by Philippoff (17), together with a means of correlating rotational-viscometer and capillary-viscometer data.

The derivations of most of the equations presented in this section on viscous flow are contained in Lapple *et al.* (13).

### Turbulent Flow

In general, non-Newtonian fluids behave similarly to Newtonian fluids in the turbulent-flow region, in that they exhibit a relatively constant apparent viscosity. The apparent viscosity in this case is generally referred to as the turbulent viscosity,  $\mu_T$ .

A typical shear diagram for pipe-line turbulent flow of a Bingham plastic is shown by the dotted branching portion of the curve in Figure 3. The point of branching corresponds to the critical Reynolds number and is lower the larger the pipe diameter. Caldwell and Babbitt (5) report that from their tests on the turbulent flow of clay and sewage suspensions (Bingham plastics) the pressure drop can be computed using the customary friction-factor-vs.-Reynolds-number plot if the viscosity of the dispersion medium and the density of the mixture are used. Wilhelm, Wroughton, and Loeffel (26) obtained values for the apparent viscosities of cement-rock-water suspensions in turbulent flow which were higher than the viscosity of the dispersion medium. Binder and Busher (3) presented data on turbulent flow of grain-water suspensions (Bing-

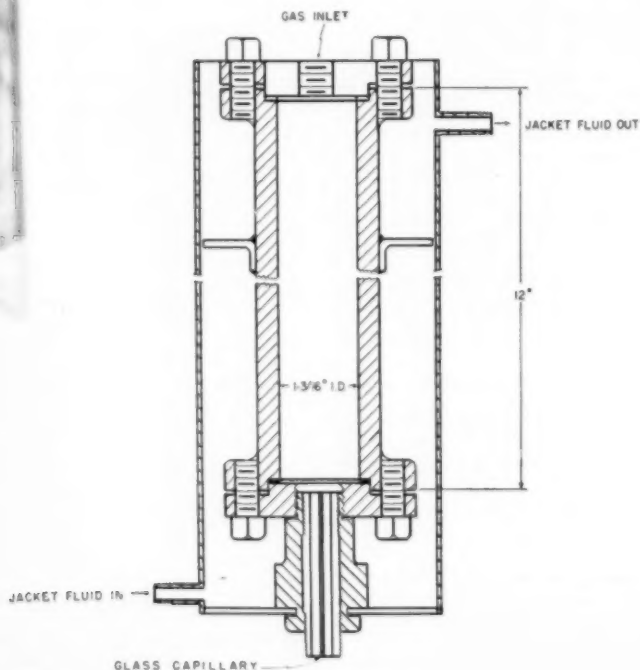


Fig. 6. Capillary-tube viscometer.

ham plastics), and the apparent viscosities were from five to ten times that of the dispersion medium.

Winding, Baumann, and Kranich (28) presented information on the flow of pseudoplastic GR-S latices. In turbulent flow, a good pressure-drop correlation was obtained by using limiting viscosity at infinite shear,  $\mu_\infty$ .

The turbulent viscosity is computed as follows from the turbulent-flow portion of the pipe-line shear diagram. A value of  $D\Delta p/4L$  is selected and the linear velocity,  $V$ , calculated from the corresponding value of  $8q/\pi D^3$ . The friction factor is then obtained from the Fanning equation

$$f = (D\Delta p/4L)(2g_c/\rho_m V^2). \quad (21)$$

The corresponding Reynolds number is then obtained from the pipe-line-friction-factor chart, and the turbulent viscosity computed from this Reynolds number.

In determining the pressure drop, or in sizing pipe lines, for turbulent flow of non-Newtonian materials, the turbulent viscosity determined from pipe-line-viscometer data and the density of the mixture are used in computing the Reynolds number, and the friction factor is obtained from the friction-factor-viscosity-Reynolds-number chart. Equation (21) is used in computing the pressure drop. Trial and error is involved in sizing the pipe line, since the diameter term appears in both the friction factor and Reynolds number. This can be avoided by using the pipe-flow chart (16). If tests cannot be made of the material in question in turbulent flow, an approximation for the turbulent viscosity can be made by using the coefficient of rigidity for Bingham plastics or the limiting viscosity at infinite shear for pseudoplastics. The pressure drop based on this approximation should be accurate to within  $\pm 25\%$ .

### Experimental Apparatus

**Rotational Viscometers.** Two standard commercial viscometers, the MacMichael and the Brookfield, were used. In the case of the MacMichael, a 2-cm.-diam. spindle was used in addition to the 1-cm.-diam. spindle supplied by the manufacturer. In the case of the Brookfield viscometer, only two of the four spindles supplied by the manufacturer had the required cylindrical shape. Consequently, an additional small spindle was provided in order to extend the range.

**Pipe-line-type Viscometers.** The design of the capillary-tube viscometer that was used in this work is shown in Figure 6. Under influence of the gas pressure, the liquid in the cylinder was forced to flow through one of a number of glass capillary tubes. These were mounted inside steel tubes by means of litharge-and-glycerine cement.

The weight rate of flow was measured by collecting this filament under a non-

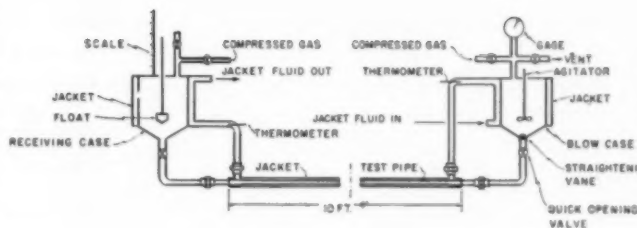


Fig. 7. Pipe-line viscometer.

volatile oil in a small beaker for a measured time interval.

A diagram of the pipe-line viscometer is given in Figure 7. The blow case was equipped with an agitator, a quick-opening valve, and a compressed-gas inlet with pressure gage and control valves. The receiving tank was equipped with a float and scale for metering purposes and a compressed-gas inlet for blow back. Three stainless-steel test pipes were used, with following inside diameters: 0.1243, 0.2547, and 0.4960 in. The test-pipe pressure drop was obtained from the blow-case pressure with suitable corrections for static head and resistance in valves and fittings. The latter was small compared with the test-pipe resistance.

A diagram of the 2-in. pipe-line system is shown in Figure 8. A water-purge system was used with the Propelloflo meter to prevent the mechanism from becoming clogged with solid particles. An air purge was used with the pressure taps on the metering elements and the test section to prevent materials from backing up into the manometer lines.

### Results

**Viscous Flow.** Examples of typical results obtained with the viscometers described above are presented in the following discussion.

Figure 9 is a logarithmic plot of the shear diagram of a 4.46% Napalm solution obtained by the use of a Brookfield viscometer. The shear stress,  $\tau_0$ , was computed by Equations (16) and (11). The straight line indicates that the exponent  $n$ , as given by Equation (14), and used in Equation (13), is a constant.

Typical MacMichael-viscometer data for a 24.8% cellulose-acetate solution are shown in Figure 10. The straight lines

show that  $n$  in Equation (13) is constant.

Capillary-tube-viscometer data of a 24.8% cellulose-acetate solution are given in Figure 11. This solution behaved as a pseudoplastic.

A shear diagram for a 23% lime slurry obtained with a pipe-line viscometer is given in Figure 12. The curve branches off at A, B, and C, respectively, indicating that turbulent flow exists along the upper branch of each curve. The curve branches off for larger size pipes at lower values of shear stress. The viscous-flow portion of the curves appears to behave as that for Bingham-type plastics except at low shear stresses. At low shear stresses the curve is similar to that for a pseudoplastic. However, it is probable that the lime slurry is of the Bingham-type plastic and that the pseudoplasticity at low shear stresses is due to slippage at the wall.

Basic data, examples shown above, were reduced to rate of shear and shear stress at the wall by means of Equations (13) and (11) respectively for rotational viscometers and of Equation (17) for pipe-line-type viscometers. Combined shear diagrams similar to Figure 5 were prepared.

Figure 13 is the combined shear diagram for the 4.46% Napalm solution. Excellent agreement was obtained between the rotational-viscometer values and the capillary-tube-viscometer values.

The combined shear diagram for the 24.8% cellulose-acetate solution is given in Figure 14. The agreement is good

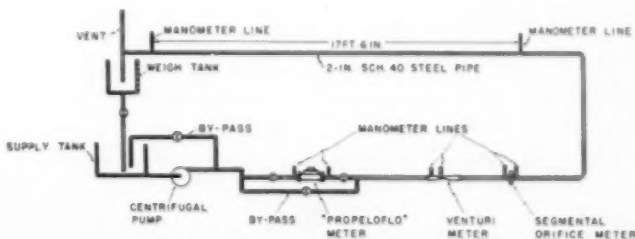


Fig. 8. Meters and test section of 2-in. pipe.

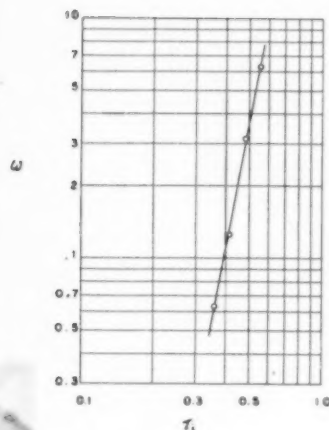


Fig. 9. Shear diagram for 4.46% Napalm from Brookfield viscometer.

○ No. 4 Spindle (0.129 in O.D.).

between the MacMichael-viscometer and capillary-tube-viscometer data; however, the Brookfield viscometer indicated about 20% lower shear stresses for the same rate of shear.

The 23% lime-slurry combined shear diagram is given in Figure 15. Good agreement was obtained between the Brookfield-viscometer and 2-in.-pipe-line data. The MacMichael viscometer gave

Fig. 10  
Shear diagram for 24.8% cellulose acetate solution from MacMichael viscometer.

○ Small spindle, 1 cm. O.D., 5 cm. high, No. 22 wire.  
△ Medium spindle, 2 cm. O.D., 5 cm. high, No. 22 wire.

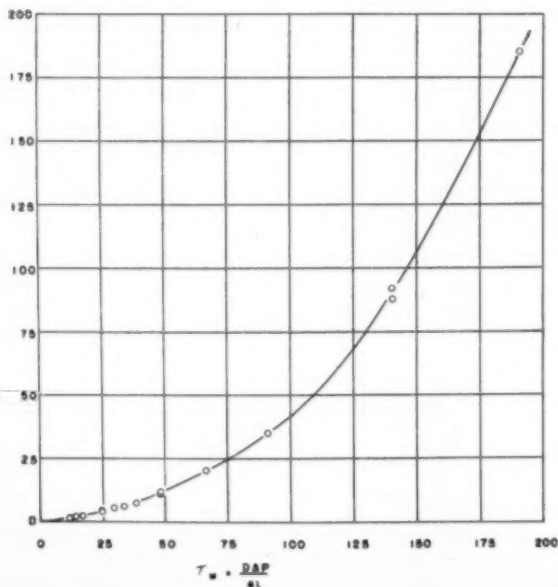
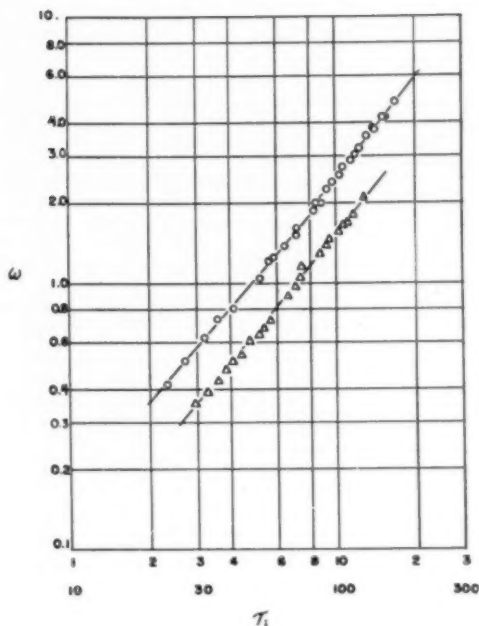


Fig. 11. Capillary tube, 0.0798-in. I.D., 5.96 in. long. Shear diagram for 24.8% cellulose acetate solution from capillary tube viscometer.

about 20% greater shear stresses for the same rate of shear. The lower portion

of the curve for the pipe-line viscometer may be in error, as the data were obtained from the lower curved portion of the curve in Figure 12. This portion of the curve is difficult to obtain because of the low flow rates and low pressure drops.

From the foregoing examples, it is seen that shear diagrams of the type indicated in Figure 3 afford a rapid method of scaling up semiworks data on flow through pipe lines. Caution must be exercised in applying this method, in that the Reynolds number must be checked to assure that the flow is viscous in the plant-size line. The method of analyzing rotational-viscometer and pipe-line data shown in Figures 13, 14, and 15 is thus useful in designing pipe lines from rotational-viscometer data.

**Turbulent Flow.** The 18% titanium-dioxide slurry in the pipe-line viscometer and in the 2-in. pipe line was in turbulent flow. The slurry had been passed through a centrifugal pump and the piping system several times prior to the tests. Previous tests on titanium-dioxide slurries of this and other concentrations gave pressure drops that were manifold greater and in addition exhibited some thixotropy. It appears as though most of the thixotropic breakdown of the 18% titanium-dioxide slurry occurred in the centrifugal pump.

The data were reduced to a plot of

friction factor vs. Reynolds number (Fig. 16). The value for the turbulent viscosity used in this figure was computed as follows.

A logarithmic plot of friction factor vs. the quantity  $DV\rho$  was prepared. Superimposed upon this was the friction-factor-vs.- $DV\rho$  curve for water as obtained on the same type of pipe (16). The lateral displacement of the slurry curve from the water curve is then a measure of the turbulent viscosity; that is, the ratio of  $DV\rho$  for slurry to  $DV\rho$  for water at a given friction factor multiplied by the viscosity of the water is the turbulent viscosity.

An average value of about 1.5 to 1.6 centipoises was so obtained for the 18% titanium-dioxide slurry. The data were then plotted in Figure 16 using this average value of the turbulent viscosity in computing the Reynolds numbers. Figure 16 indicates that the turbulent viscosity is approximately constant for this material. The use of the turbulent viscosity therefore affords a convenient method of scaling up semiworks data for the design of pipe lines conveying non-Newtonian slurries and solutions in turbulent flow.

### Design Procedure

The steps to be used in scaling up or sizing pipe lines from either pipe-line- or rotational-viscometer data are outlined below. The computed pressure drop using pipe-line-viscometer data should be within approximately  $\pm 25\%$  of the actual pressure drop and, using

rotational-viscometer data, within  $\pm 50\%$  of the actual pressure drop.

In general, the design procedure con-

sists of obtaining the shear diagram for the material, of determining the type of material, and of applying the proper re-

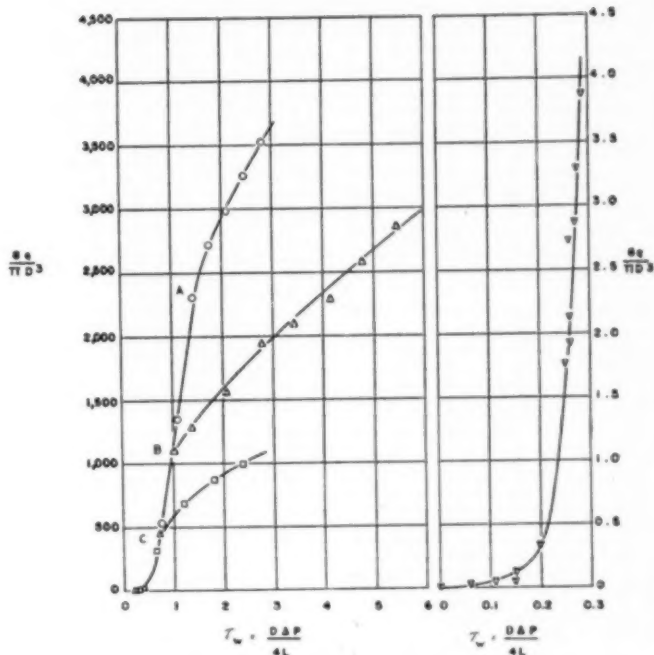


Fig. 12. Shear diagram for lime slurry from pipe-line viscometer and pipe line. Lime slurry, 23% by weight.

○ 1/8-in. tube; △ 1/4-in. tube; □ 1/2-in. tube; ▽ 2-in. pipe.

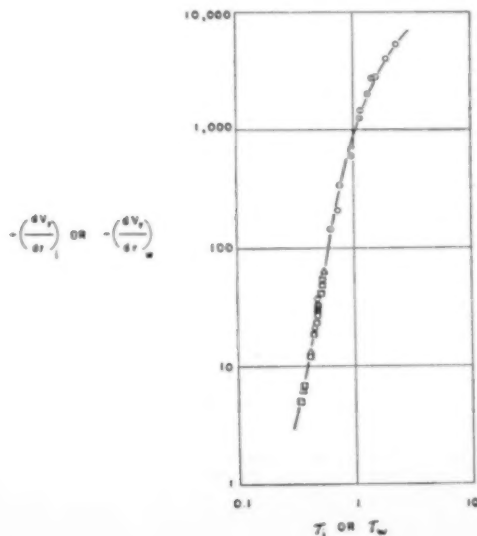
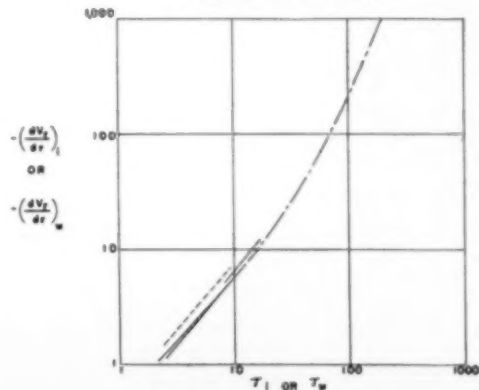


Fig. 13. Combined shear diagram for 4.46% Napalm.

○ Pipe-line viscometer; △ Brookfield viscometer; □ MacMichael viscometer.

Fig. 14. Combined shear diagram for 24.8% cellulose acetate solution. ▽ MacMichael viscometer. --- Brookfield viscometer. - - - Capillary tube viscometer.





relationship pertaining to the specific type of material in order to determine the pressure drop or to size the pipe line. If the material is Newtonian, the usual methods of design apply using the density and viscosity of the material. If the material is non-Newtonian, the shear diagram can be used directly for design purposes in the viscous-flow region; for turbulent flow, the turbulent viscosity can be obtained from pipe-line-viscometer data or can be computed from the shear diagram, and then the usual methods of design can be applied.

#### Scale Up from Pipe-line-viscometer Data.

**Pipe-line-viscometer Measurements.** The pipe-line-viscometer measurements should be obtained with at least two pipes of different inside diameters and of a given length, except for thixotropic materials, where a third diameter facilitates interpolating of data with respect to pipe diameter.

**Preparation and Analysis of Shear Diagram.** From the data and dimensions of the pipe, an arithmetic plot is made of  $8q/\pi D^3$  vs.  $\Delta P/4L$ .

A single curve is generally obtained in the viscous region for all pipe dimensions and any one material, with the exception of those exhibiting thixotropic behavior.

If the curve is a straight line from the origin, the material is Newtonian. If the material is thixotropic, a separate curve is

obtained in the viscous region for each pipe diameter or pipe length.

If curves similar to Figure 3 are obtained, the flow for the portion above the branching point is turbulent, and, for the portion below, the flow is viscous. If all of the data produce only one curve similar to curve D of Figure 1, the material is dilatant.

**First Approximation for Scale up of Pipe Line.** If the material is Newtonian, the usual methods of sizing pipe lines should be employed.

For Bingham-plastic, pseudoplastic, and dilatant materials, the diameter of a pipe line for a specific rate of flow, length, and pressure drop can be obtained directly from the shear diagram.

If the material is thixotropic, curves for pipe lines of other diameters can be drawn in the shear diagram by interpolation or extrapolation of the known curves. The procedure for sizing is then the same as above, except that the curve representing the proper diameter should be used.

**Checking for Viscous or Turbulent Flow.** The Reynolds number in the final pipe should be computed using the density of the mixture and the turbulent viscosity or coefficient of rigidity or the limiting viscosity at infinite rate of shear.

If the Reynolds number is less than 2100, the flow can be considered viscous; if the Reynolds number is 2100 or greater, the flow may be turbulent.

**Viscous Flow—Scale up of Pipe Line.** The values obtained by the methods outlined above are satisfactory.

**Turbulent Flow—Scale up of Pipe Line.** The pipe line is scaled up by the usual methods employing the friction-factor-vs.-Reynolds-number curves for turbulent flow. The Reynolds number is computed as above.

#### Sizing from Rotational-viscometer Data.

**Measurements.** The data to be obtained are the scale readings corresponding to the rotational speeds. Up and down curves should be taken to detect thixotropic effects.

**Preparation and Analysis of Shear Diagram.** An arithmetic plot is made of the shear stress at the inner cylinder wall, Equations (15) and (11), or Equations (16) and (11), vs. the rotational speed. The rate of shear for various values of shear stress can then be computed from the slope of this curve and Equation (13).

Using the values of the rate of shear and the shear stress, a logarithmic plot is made similar to Figure 5. The upper portion of the curve has an asymptote of unit slope if the material is a Bingham plastic or pseudoplastic, and from points on this asymptote the coefficient of rigidity or the limiting viscosity for infinite rate of shear can be computed.

An arithmetic shear diagram is then made of the rate of shear and shear stress, using either the coefficient of rigidity or the limiting viscosity for infinite rate of shear. From this shear diagram, similar to Figure 1, the viscosity function, such as Equation (4), can be obtained.

**Sizing of Pipe Lines.** For Bingham plastic and pseudoplastic materials the viscosity function can be used with the usual

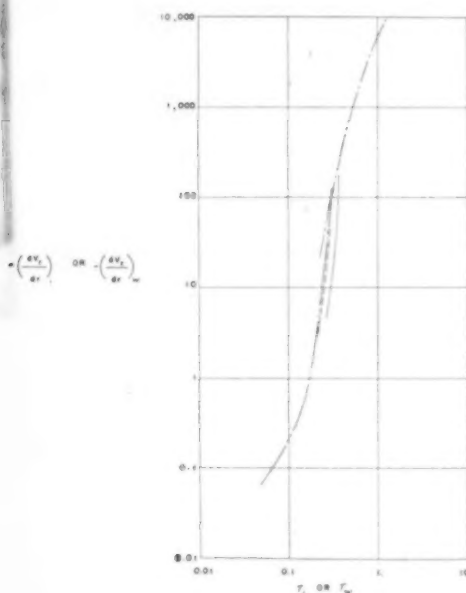


Fig. 15.

Combined shear diagram for 23% lime slurry.

- MacMichael viscometer.
- - - Brookfield viscometer.
- · - · - Pipe-line viscometer.
- - - 2-in. pipe line.

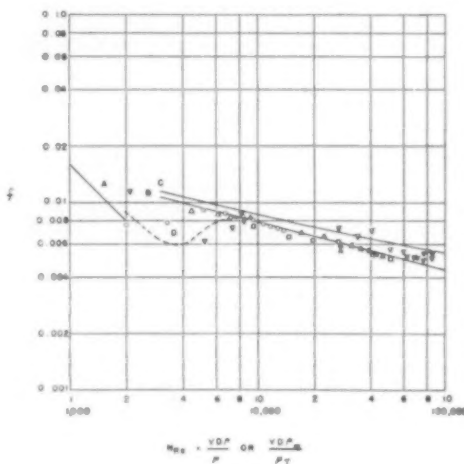


Fig. 16.

Friction factor vs. Reynolds number. Use of turbulent viscosity.

- Curve A: Viscous flow.
- Curve B: Turbulent flow, smooth pipe.
- Curve C: Turbulent flow, commercial pipe.
- Curve D: Transition, water flow in 1/4-in. tube.

- 18%  $\text{TiO}_2$  slurry, 1/4-in. tube.
- △ 18%  $\text{TiO}_2$  slurry, 1/2-in. tube.
- 18%  $\text{TiO}_2$  slurry, 1/2-in. tube.
- ▽ 18%  $\text{TiO}_2$  slurry, 2-in. pipe.

methods of design. A check should be made for regime of flow, and, if turbulent flow, the procedure outlined under pipe-line viscometers can be applied.

For dilatant materials and for a more accurate, but yet approximate, method for Bingham-plastic and pseudoplastic suspensions, an equation for the rate of shear as a function of the shear stress, Equation (18), is determined from an arithmetic plot of the shear diagram. This function is substituted into Equation (17), giving Equation (19). Equation (19) is then integrated in order to obtain the equation of the shear diagram for pipe lines, similar to the viscous-flow portion of Figure 3. The remainder of the procedure is the same as for pipe-line-viscometer data.

### Comments on Pump Selection

Almost no information is available in the literature on the selection of pumps for non-Newtonian materials; therefore a few high-spot comments are included herein.

In pumping Bingham-plastic, pseudoplastic, and thixotropic materials, a centrifugal pump can be used. The head and efficiency as given for water can be corrected for the material to be pumped by means of the head and efficiency factors. These factors are given (23) as a function of a pump Reynolds number. This Reynolds number can be based on the density of the mixture and the turbulent viscosity. If the turbulent viscosity has not been determined, the coefficient of rigidity for Bingham plastics or the limiting viscosity,  $\mu_\infty$ , for pseudoplastics can be used. Open impellers should be employed where the particle size is large or where the particles would tend to plug the small passages in a closed impeller. A centrifugal pump produces high rates of shear and thus reduces the viscosity of the material, a desirable result from the pumping standpoint; however, degradation and dispersion of the particles may take place and in some cases be undesirable. For these applications it may be preferable to use diaphragm pumps or, in some cases, piston pumps. Rotary-gear pumps can be used for solutions of these types but cannot be used with suspensions because of the rapid wear.

In pumping dilatant materials, it is necessary to use a slow-moving, low-rate-of-shear pump in order to keep the viscosity of the material as low as possible. Pumps of this type are diaphragm, squeegee types, piston, and screw.

Flow cases can be used for any type of material. Agitation may be required for cases of rapidly settling solids. Care should be exercised not to permit air to enter the line, as it is very difficult to separate the air from plastic and viscous materials.

### Notation

- $B_1$  = rotational-viscometer instrument constant, 1/cu.ft.  
 $B_2$  = rotational-viscometer instrument constant, 1/cu.ft.  
 $d$  = differential operator, dimensionless  
 $D$  = inside diameter of tube or pipe, ft.  
 $f$  = pipe-flow friction factor, dimensionless  
 $g_s$  = conversion factor, 32.17 (lb./lb. force) (ft./sec.<sup>2</sup>)

- $h$  = inner cylinder (bob or spindle) height, ft.  
 $k$  = MacMichael-viscometer torsional constant, (ft.-lb. force)/radian  
 $L$  = length of tube or pipe, ft.  
 $n$  = an exponent, a constant  
 $N_{Re}$  =  $(Dl^2\rho/\mu)$  = Reynolds number, dimensionless  
 $q$  = volume rate of flow, cu.ft./sec.  
 $r$  = radius at a point, ft.  
 $r_i$  = inner cylinder (bob or spindle) radius, ft.  
 $r_o$  = outer cylinder (bob or spindle) radius, ft.  
 $R$  = radius of pipe, ft.  
 $T$  = torque, ft.-lb. force  
 $T_y$  = torque intercept, ft.-lb. force  
 $V$  = average velocity, ft./sec.  
 $V_r$  = local velocity at radius  $r$ , ft./sec.  
 $-(dl'/dr)$  = rate of shear, (ft./sec.)/ft.  
 $-(dl'/dr)_i$  = rate of shear at inner cylinder wall, (ft./sec.)/ft.  
 $-(dl'/dr)_w$  = rate of shear at tube wall, (ft./sec.)/ft.  
 $\Delta p$  = pressure drop due to friction, lb. force/sq. ft.  
 $\eta$  = coefficient of rigidity, lb./ft. (sec.)  
 $\theta_M$  = torsion wire deflection, radians  
 $\mu$  = viscosity, lb./ft. (sec.)  
 $\mu_a$  = apparent viscosity, lb./ft. (sec.)  
 $\mu_B$  = Brookfield viscosity reading, lb./ft. (sec.)  
 $\mu_i$  = viscosity at inner cylinder wall, lb./ft. (sec.)  
 $\mu_o$  = viscosity at outer cylinder wall, lb./ft. (sec.)  
 $\mu_s$  = viscosity at zero rate of shear, lb./ft. (sec.)  
 $\mu_T$  = turbulent viscosity, lb./ft. (sec.)  
 $\mu_\infty$  = limiting viscosity at infinite rate of shear in viscous flow, lb./ft. (sec.)  
 $\rho$  = density, lb./cu.ft.  
 $\rho_m$  = density of solution or suspension, lb./cu.ft.  
 $\tau$  = shear stress, lb. force/sq.ft.  
 $\tau_i$  = shear stress at inner cylinder wall, lb. force/sq.ft.  
 $\tau_r$  = shear stress at radius  $r$ , lb. force/sq.ft.  
 $\tau_w$  = shear stress at tube wall, lb. force/sq.ft.

- $\tau_y$  = yield stress or pseudo yield stress, lb. force/sq.ft.  
 $\psi$  = a function  
 $\omega$  = angular velocity, radians/sec.  
 $\omega'$  = rate of rotation, rev./min.

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# THE REDUCTION OF NICKEL OXIDE

## In a Fluidized Bed

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THE phenomena involved in the so-called fluidized bed have been extensively described within the past five years. Murphree and his associates (22); Parent, Yagol and Steiner (23); and Kalbach (4, 5) have discussed the subject in a general way, describing its present applications and possible future ones and setting forth qualitatively the effects upon the pressure drop across the bed of such variables as fluid density and velocity, particle size and density, fraction voids, and size distributions.

The bulk of quantitative work on the subject has been concerned with correlations between pressure drop and the several properties of the fluid and solid involved, both for batch and continuous fluidization, in order to permit the prediction of the onset of fluidization from readily measurable properties of the components of the systems studied and to relate the fluidization phenomena to earlier work on the general problem of fluid flow and pressure drop through porous solids and randomly packed beds. Such correlations have been made by Wilhelm and Kwauk (30), Morse (21), Leva and his co-workers (8-11, 13), Lewis, Gilliland, and Bauer (14), and Ergun and Orning (2). The heat-transfer characteristics of fluidized beds have been studied by Mickley and Trilling (20), Leva and his co-workers (12), and Kettenring, Manderfield, and Smith (6).

Mass transfer in such beds has been studied by McCune and Wilhelm (19), Resnick and White (24), and Kettenring, Manderfield and Smith (6). In all cases the systems used were such that the solid particles involved were in no case smaller than 100 mesh. Gas and solid mixing in fluidized beds was studied by Gilliland and Mason (3).

Chemical reactions in fluidized beds

have also been considered. Lewis, Gilliland, and their co-workers studied the gasification of carbon by carbon dioxide (16) and by metal oxides (18) and the

reaction between methane and copper oxide (17) and iron oxides (15). The data for the carbon-carbon-dioxide system were correlated by an equation of

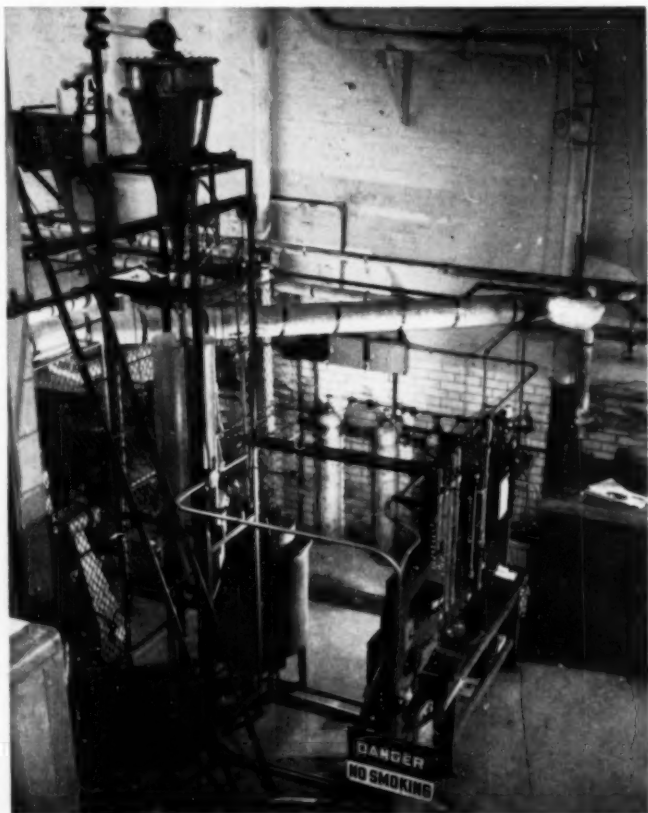


Fig. 1. Photograph of apparatus.

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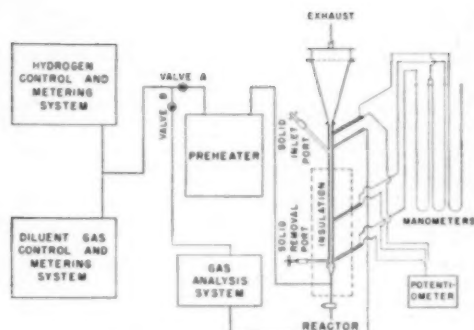


Fig. 2. Schematic sketch of apparatus.

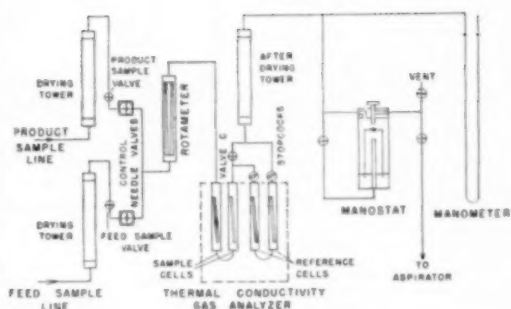


Fig. 3. Gas analysis system.

the Langmuir type. It was noted that at low temperatures the system approached the equilibrium between the gas mixture and carbon, while at high temperatures the reaction rates were far higher than those calculated from the correlation. The system appeared to be independent of the rate at which gas passed through the reactor, except insofar as that rate varied the over-all gas composition. In the case of the methane-copper-oxide system, it was assumed that the factor limiting the reaction was the reaction of carbon dioxide and water vapor with methane; i.e., it was assumed that chemical kinetic factors were rate controlling. The work on gasification of carbon by metal oxides dealt with reaction mechanisms, chemical equilibria, and reaction kinetics. In the reaction between methane and iron oxides, reaction rate was studied as a function of temperature and degree of reduction; a study of reaction mechanisms was also made.

No previous work has been reported in which a reaction taking place in a fluidized bed was affected to any appreciable degree by the rate of gas flow through the bed. That is, in all work reported thus far, the mass transfer—which would be expected to vary as a function of the gas velocity—did not affect the over-all reaction rate, since in each case a kinetic step was the slowest and therefore the rate-determining step.

The present paper deals with experiments involving the rate of reduction of finely divided solid nickel oxide with hydrogen. The results obtained indicate that both a kinetic-reaction step and a diffusional, or mass-transfer, step affect the over-all reaction rate.

### Theory

The reduction of nickel oxide by hydrogen was studied by Benton and Emmett (1). They observed that for oxide prepared by the decomposition of nickel nitrate, the progress of the reac-

tion was marked by a sharp acceleration, came to a peak, and then fell off rapidly to a low value. They did not observe any pronounced peak with commercial-grade oxide. They believed that the acceleration was due to autocatalysis of the oxide-metal interface.

It was also observed that the peak occurred earlier and to a greater extent if the oxide had been formed at a low temperature rather than a higher one. Further, the peak was higher, in the case of two oxide samples formed at the same temperature, for the sample reduced at the higher temperature. They explained this by stating that at the higher reduction temperatures, the reaction occurred at a greater number of points.

In studying the over-all rate of a chemical reaction, several steps in series must be considered, any one of which may be so much slower than the others that it substantially controls the over-all rate. Among these are kinetic steps, such as activated adsorption of a reactant on the solid surface, the chemical reaction *per se*, and the desorption of the reaction products; and so-called diffusion or mass-transfer steps. Included in the latter are the movement of reactants from the main gas body into that region of the reactor in which reaction occurs, the diffusion of reactants through the inert film surrounding the solid particles, the back-diffusion of reaction products through the same film, and the removal of those reaction products to the main gas body. According to Wilhelm (29), the over-all reaction constant may be related to the diffusion and reaction constants by an equation of the form

$$1/U = 1/k_d + 1/k_r$$

where  $k_d$  is an over-all diffusion or mass-transfer coefficient and  $k_r$  is a first-order (or pseudo-first-order) reaction constant. Of the two,  $k_d$  is likely to depend largely on the mechanical properties of the reactor and relatively little on tem-

perature, while  $k_r$  should increase markedly with increase in temperature. Two extreme possibilities exist: at high temperatures, the diffusional steps may be by far the slower;  $1/k_d$  will be larger than  $1/k_r$ , and the process will be diffusion controlled.

Alternately, at low temperatures,  $1/k_r$  may far exceed  $1/k_d$ , and the reaction rate will control the process. Between these two extremes, a wide range of intermediate cases may exist in which both terms are comparable.

In the case of the fluidized bed, the variables that affect the diffusional properties of the bed are particle size, gas velocity and viscosity, the nature of the particle shape and surface, and the nature of the fluidization. If the same solid were used repeatedly, or samples of the same batch of solid, it is seen that only the gas properties may, in their variation, alter the diffusion steps. Hence in a case in which the process is at all affected by mass transfer, the gas properties should have a marked effect upon the over-all process rate. It was the purpose of this work to determine whether either the diffusion or reaction step was controlling or whether both affected the over-all rate in the case of the reduction by hydrogen of nickel oxide. Nickel oxide was chosen because of the apparent simplicity of the system involved: only one reaction was to be expected and only one solid product; and the calculations involved were also simplified by the fact that one mole of each reactant yielded one mole of each expected product.

### Apparatus

The apparatus used in this work is shown on Figures 1 and 2. The reactor was a 68-in. length of 2-in. I.P.S. type-304 stainless-steel pipe, with flanged ends, wound with nichrome wire. The base of the reactor was a 15° cone made of stainless steel type 303. A 200-mesh stainless-steel wire cloth prevented the solids from passing into the cone. There were three pressure taps as shown and wire-in-tube thermocouples,

the hot junctions of which could be moved in a lateral traverse of the reactor; in this work, the junctions were located on the center line of the reactor. The wound reactor tube was placed in a 16-in.-diam. sheet-metal cylinder packed with rock wool.

Operation was by batches so far as the solids were concerned. Nickel oxide was introduced through a solids feed port at the top of the reactor and was removed through a solids exit port near the bottom.

Exit gases from the reactor passed through a stainless-steel cone, covered with a 200-mesh braided stainless-steel-wire cloth to prevent loss of fines. A bin knocker periodically returned accumulated fines to the reactor.

Rotameters measured inlet gas streams. The feed-gas sample was withdrawn immediately before the preheater, the product sample from the top of the reactor. Each sample was drawn through a glass-wool filter and a silica-gel drier before entry into the analytical system (see Figure 3). The pressure taps were kept open by a measured stream of gas.

### Analytical Method

The reaction was followed by means of a continuous hydrogen analysis, performed by a Leeds and Northrup thermal-conductivity gas analyzer and Micromax recorder. During each observation, a feed-gas sample was drawn through the analyzer to determine its hydrogen content. Throughout the remainder of the run, a sample of the exit gas was analyzed to provide a continuous record. To obtain consistent analyses, it was necessary to maintain a constant pressure and a constant flow rate through the analyzer.

At ultimate sensitivity, the analyzer indicated voltage variations of 0.1 mv., corresponding to one-tenth of the smallest scale division on the recorder chart, or the smallest change of position which could reliably be detected. This corresponded to a variation of 0.01% hydrogen in a stream containing about 20% hydrogen. The analyzer was able to reproduce a reading to within 0.2 mv., or two-tenths of the smallest scale division on the recorder chart, corresponding to 0.02% hydrogen. Thus, the precision of a given reading was 0.02% hydrogen in 20%, or one part in one thousand. Hence if the difference between a given feed and product were as little as 0.1% hydrogen, corresponding to one scale division, that difference could be considered as correct to  $\pm 10\%$ . The larger the difference between the feed and product compositions became, the smaller was the relative error and the greater the precision to which that difference could be measured.

The accuracy of any one reading could not be greater than that of the calibration. Calibration was by a flow method, the hydrogen and nitrogen streams being individually measured by rotameters, and was expressed by a least squares straight line in the narrow range (ultimate sensitivity calibration) with a standard deviation of 0.092% hydrogen in about 20%; hence, the standard deviation was about 0.5% of the observed reading. Any reading of hydrogen composition therefore might vary by nearly 0.1% from the true composition; however, since the two analyses involved in each rate calculation were entirely consistent, the precision of each

rate calculation depended upon the relative precision of the two individual analyses, and not upon their absolute accuracy.

With small differences between feed and product compositions in which the ultimate instrument sensitivity was called for, the analytical results might have erred by  $\pm 10\%$ . When the composition difference amounted to ten scale divisions at the ultimate sensitivity, the analytical results could have been in error by  $\pm 1\%$ . As the reaction rate increased and the difference between product and feed increased still further, the analytical precision did not increase. First, for wide composition variations, it was necessary to use a wide-range calibration, which was a curve to which no equation was fitted; this calibration was inevitably subject to greater uncertainty than the narrow-range calibration. Second, at high reaction rates the product composition was subject to rapid fluctuation. To calculate an average reaction rate over a reasonable time interval, an averaged product composition was used. Since the instantaneous product composition varied from the average value used in the rate calculation by as much as  $\pm 5\%$  of the total composition difference, the rate calculated was necessarily subject to error.

It is, however, a conservative claim that at no time was the analysis subject to error of greater than  $\pm 10\%$  and in most cases was well below half that figure.

### Materials

The nickel oxide used was pigment-grade oxide DP fractionated through 65 mesh and retained on 200 mesh, obtained in a 100-lb. lot from the Ceramic Color and Chemical Manufacturing Company of New Brighton, Pa. Batches for the reactor charge were taken when required from this lot, and all were assumed to be uniform in composition and in size distribution.

The hydrogen was 99.5% hydrogen obtained from the Paschall Oxygen Company; the diluent was Seaford grade nitrogen obtained from the Air Reduction Company.

### Procedure

A weighed batch of nickel oxide was introduced into the reactor, and a stream of nitrogen sufficient to fluidize the bed was turned on. The preheater and reactor heaters were allowed to bring the system up to the desired temperature.

As the temperature was approached, the hydrogen and nitrogen flows were set at the desired values for the standard cell of the gas analyzer. A sample was drawn through the standard and sample cells in series. When the recorder indicated that the standard cell composition was constant, it was isolated, and all succeeding gas samples passed through the sample cell alone.

The gas rates were then set to give a stream approximately 20% hydrogen and were maintained constant. The product sample was then drawn through the ana-

lyzer and observed for 1 hr. in most cases. At the end of that time, a feed sample was taken for 10 or 15 min. When both product and feed compositions had been recorded, the gas rates were altered to give a different total gas flow with approximately the same composition, and the procedure was repeated.

Throughout each run, the flow rates and bed temperatures were maintained constant by manual control. Pressure drop across the bed was observed to check on fluidization.

Runs were made in order both of increasing total gas flow and of decreasing gas flow to determine whether any difference in behavior might be noted. A single batch of solid might be run at a single temperature on several successive days, or at different temperatures on succeeding days, to determine whether changes occurring in the solid due to different temperatures were reversible.

### Results

The range of the independent variables covered is as follows: temperature: 350° to 750° F., mole fraction hydrogen in feed: 0.1730 to 0.2505, superficial linear gas velocity (calculated at the bed temperature): 0.312 to 1.43 ft./sec., and weight of nickel oxide in charge: 3.6 to 5.5 lb.

The only dependent variable measured was mole fraction of hydrogen in the product gas, from which the reaction rate and over-all specific-reaction constant were computed.

The reaction rate was computed by the equation

$$R' = (X_f - X_p) \cdot N \cdot 60$$

where

$R'$  = reaction rate in moles/hr.

$X_f$  = stoichiometric hydrogen concentration in the feed, moles hydrogen/mole nitrogen

$X_p$  = stoichiometric hydrogen concentration in the product, moles hydrogen/mole nitrogen

$N$  = nitrogen flow, moles/min.

But

$$X_f = \frac{x_f}{1 - x_f}$$

and

$$X_p = \frac{x_p}{1 - x_p}$$

and

$$N = \frac{v(1 - x_f)}{359}$$

where

$x_f$  = mole fraction hydrogen in the feed

$x_p$  = mole fraction hydrogen in the product

$v$  = feed-gas flow rate, cu.ft./min. at standard conditions

\* This assumes a negligible H<sub>2</sub>O concentration, which was always the case.



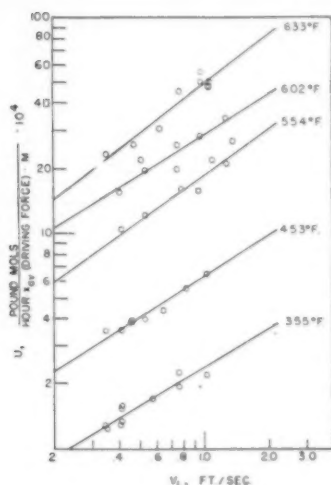


Fig. 4. Variation of  $U$  with  $V_L$ .

The specific-reaction constant was defined by the equation

$$U = \frac{2R'}{M(x_f + x_p)}$$

where

$M$  = weight of unreacted oxide present at the time for which the specific-reaction constant applies;

$\frac{x_f + x_p}{2}$  = average driving force, mole fraction hydrogen.

The weight of unreacted oxide present at any given time is computed by the relation

$$M = M_0 - \Sigma M_r$$

where

$M_0$  = initial weight of the charge  
 $M_r$  = weight of oxide reduced in each run =  $R' \cdot \theta \cdot 74.8$ ,

where

$\theta$  = duration of each run, hr.  
 74.8 = lb. molecular weight of nickel oxide.

Hence, in terms of the observable quantities,

$$U = \frac{2 \left( \frac{x_f}{1-x_f} - \frac{x_p}{1-x_p} \right) v (1-x_f) 60}{(x_f + x_p) 359 [M_0 - \Sigma (R' \cdot \theta \cdot 74.8)]}$$

The superficial linear gas velocity was computed by the equation

$$V_L = \frac{v(t + 460)}{(492)(60)(0.02330)}$$

TABLE 1.—SUMMARIZED DATA AND CALCULATIONS FOR RUNS BELOW 700° F.\*

Run	$v$ cu.ft./min.	$t_{exp}$ * F.	$V_L$ ft./sec.	$x_f$	$x_p$	$U \times 10^4$ Charge	$M_0$
DN-1-A	0.348	356	0.413	0.2063	0.2042	1.54	6
DN-1-B	0.485	360	0.577	0.2120	0.2103	1.70	4.80
DN-1-C	0.639	359	0.761	0.2096	0.2082	1.94	
DN-1-D	0.348	360	0.414	0.2053	0.2038	1.57	
DN-2-A	0.297	347	0.348	0.1916	0.1897	1.27	
DN-2-B	0.348	347	0.408	0.2054	0.2037	1.29	
DN-2-C	0.639	357	0.760	0.2079	0.2063	2.25	
DN-2-D	0.874	354	1.03	0.2036	0.2024	2.30	
DN-2-E	0.297	352	0.351	0.1930	0.1912	1.24	
DN-2-F	0.348	353	0.411	0.2063	0.2045	1.34	

\* Only the data for one temperature are shown. The complete experimental data are on file in the Department of Chemical Engineering, University of Pennsylvania, Philadelphia 4, Pa.

where

$V_L$  = superficial linear gas velocity at bed temperature, ft./sec.

$t$  = average bed temperature throughout the run, ° F.

The reactor was a 2-in. pipe, whose cross-sectional area was 0.02330 sq.ft.

The experimental data and related calculations for the runs at temperatures below 700° F. are presented in Table 1. For runs at 700° F., the data are presented in Figures 6 and 7.

#### Variation in $U$ with Gas Velocity.

In all cases,  $U$  increased with the linear velocity of the gas through the bed. For the runs at temperatures below 700° F., the variation lends itself readily to quantitative expression, according to an equation of the form  $\log U = a + b \log V_L$ . The equations were found by the method of least squares. See Figure 4 and Table 2. There are several explanations possible for an increase in rate with gas velocity; these are treated in detail under Comment.

A similar increase in reaction rate with gas velocity was observed by Wetherill and Furnas (28), who reduced iron-ore samples in a fixed bed with hydrogen and carbon monoxide and noted

that the reaction rate for a given ore sample increased roughly as the square root of the gas velocity.

#### Variation in $U$ with Temperature.

In all cases,  $U$  increased as did reaction temperature. In order to express this variation quantitatively for runs made at temperatures below 700° F., values for  $U$  at a velocity of 1.0 ft./sec. were taken from Figure 4 at each temperature; then  $\log U$  was plotted vs.  $1/T$ , as shown in Figure 5. Inasmuch as  $U$  may be considered as a reaction constant, the Arrhenius equation may be supposed to apply; that is,  $\ln U = A' - E/RT$ . The value of  $E$  was found by the method of least squares to be 18,400 B.t.u./lb. mole, or 10.2 kg.-cal./g.mole. Taylor (26) has stated that for the adsorption of hydrogen on activated metal-oxide surfaces, the energy of activation was observed to be 10.5 kg.-cal./g.mole. It is not thought that these experiments showed a confirmation of Taylor's figures; the temperature of the experiment and the oxides involved differed. But it is at least reasonable to conclude that the energy of activation of this reaction is of the same order of magnitude as the energy of activation for the adsorption of hydrogen and that it may well be that the activated step which contributes to a large degree in setting the rate of this reaction is the adsorption of hydrogen.

#### Variation in $U$ with Reaction Time.

At temperatures below 600° F., the reaction constants were observed to be invariant with reaction time; that is, with the fraction of the charge reduced. For the runs at 600° F. (DN-10 and DN-11), the specific-reaction constant was observed to fall off slightly during each run. At the end of these runs, which amounted to 10 hr., the charge was 32% reduced. For the runs at 635° F. (DN-5

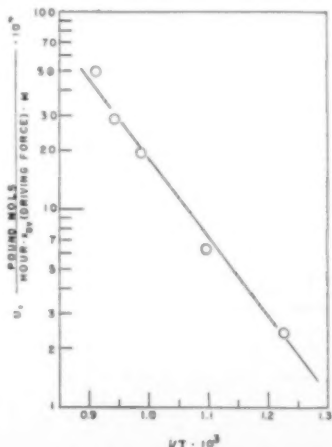


Fig. 5. Variation of  $U$  with  $1/T$ .

TABLE 2.— $U = a(V_L)^b$

Series	$t_{exp}$	$a$	$b$
DN-1	355	$2.39 \times 10^{-4}$	0.60
DN-2	353	$6.27 \times 10^{-4}$	0.72
DN-9	554	$19.0 \times 10^{-4}$	0.63
DN-10	602	$28.9 \times 10^{-4}$	0.63
DN-11	602	$28.9 \times 10^{-4}$	0.63
DN-5	633	$49.3 \times 10^{-4}$	0.78
DN-6	633	$49.3 \times 10^{-4}$	0.78

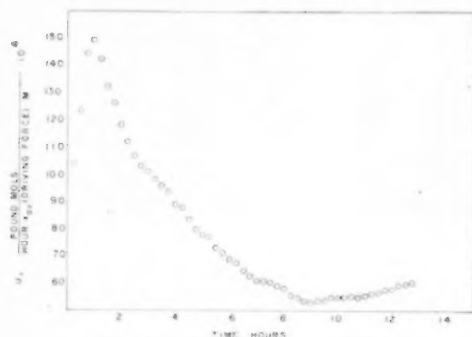


Fig. 6. Variation of  $U$  with time at  $700^{\circ}\text{F}$ .

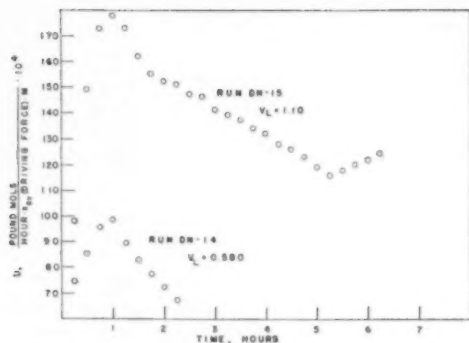


Fig. 7. Variation of  $U$  with time at two velocities.

and DN-6) the reaction constant was observed to fall off with time to a more pronounced degree than at  $600^{\circ}\text{F}$ ., although the variation was small in comparison with the reaction constant itself. At the end of runs lasting 12.5 hr. the charge was 51% reduced. Using this same charge at  $450^{\circ}\text{F}$ ., the reaction constant was invariant with time. During those runs, an additional 8% of the original charge was reduced, but the reaction constant did not fall off during that reduction.

At  $700^{\circ}\text{F}$ . and above, there was considerable variation in specific-reaction constant with time. At first a sharp increase occurred in the constant, which then diminished steadily until a point was reached at which it began to rise, slowly, again (see Figures 6 and 7). Because of the extreme variation in  $U$  with time at these temperatures, it is not reasonable to compare these values of  $U$  with those obtained at lower temperatures. It is readily apparent that, qualitatively speaking,  $U$  is higher at  $700^{\circ}\text{F}$ . than at  $633^{\circ}\text{F}$ . For the same reason, it is difficult to arrive at a quantitative comparison for the values of  $U$  obtained at several gas velocities at  $700^{\circ}\text{F}$ .; hence the data for those runs are not listed. However, it is apparent from Figure 8 that once the reaction is well under way,  $U$  is always greater the higher the gas velocity.

Benton and Emmett (1), in describing the reaction, explained that the sharp initial rise was due to autocatalysis effected by the phase boundary between the newly formed metallic nickel and the nickel oxide. They postulated the reaction mechanism to be as follows: The oxygen atoms at the interface are highly activated and hence are readily removed by hydrogen adsorbed on the nickel. As the temperature rises, the reaction is able to occur at a greater number of active centers initially; once the reaction has begun, it proceeds more

rapidly at high temperatures both because of the increased readiness of the hydrogen to react and because there exists, owing to the presence of the nickel formed at the start of the reaction, a phase boundary which catalyzes the reaction.

One would therefore expect that if reaction had begun at a high temperature and were continued at a lower one, it would proceed more rapidly than if the reaction began and proceeded at the same low temperature. This is seen to be the case. The series-DN-7 runs at  $450^{\circ}\text{F}$ . were performed on charge 9, which had formerly been used for the series at  $635^{\circ}\text{F}$ . In spite of the fact that the charge was 51% reduced at the start of DN-7, the values of  $U$  throughout the run are far higher than the corresponding values of  $U$  for runs of series DN-8 and DN-9, which were started and continued at about  $450^{\circ}\text{F}$ .

As the surface of the nickel oxide crystals becomes reduced, the reaction interface moves into the crystal itself. A reduction in reaction constant might then be expected because an additional resistance is present, the resistance to

the diffusion of hydrogen through the reduced metal to the reaction interface and to the back diffusion of the water formed by reaction. There was no evidence at all of this added resistance in runs below  $600^{\circ}\text{F}$ . At  $600^{\circ}$  and  $633^{\circ}\text{F}$ ., the reaction constant diminished but very slightly in view of the fact that the reduction had proceeded to a great extent, more than 50% in the case of charge 9, reacted at  $633^{\circ}\text{F}$ . It appears that the rate of diffusion of hydrogen within the crystal is sufficiently great to maintain the rate of reduction only slightly diminished.

It is seen from Figure 8 that the peak occurs more rapidly at low values of  $V_L$  and the diminution in  $U$  consequently begins at a lower fraction of the oxide reduced or a higher value of  $M/M_0$ . Since all runs shown on Figure 8 take place at the same temperature, there must initially have been the same number of active reaction centers. On the basis of these data, it appears that the increase in reaction rate at higher gas velocities causes either one of two things to occur: first, that a greater number of reactive centers, relative to

Fig. 8. Variation of  $U$  with fraction to be reduced at three velocities.

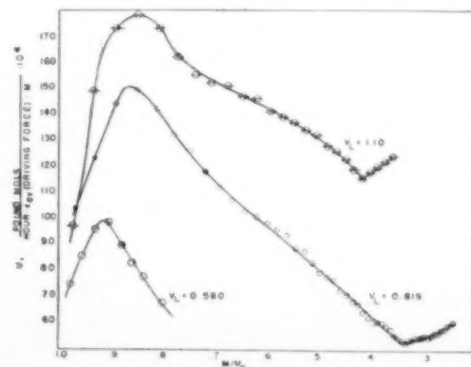


TABLE 2.—CALCULATED VALUES OF MASS TRANSFER AND REACTION COEFFICIENTS

$V_L$	$U$	$1/U$	$1/k_g'$	$1/k_r'$	$1/k_g''$	$1/k_r''$
0.412	0.000032	31,300	31.0	31,269	13.2	31,287
0.791	0.000050	20,000	13.5	19,986	6.7	19,993
1.37	0.000075	13,333	6.7	13,326	5.1	13,328

\* (6), † (24).

the amount of reduction, are formed; or, second, that the orientation of those centers either on the face or within the crystal is such as to increase their efficiency.

### Comment

It was previously observed that the specific-reaction constant increased with increase in gas velocity. There are several possible causes for such an increase.

A portion of the gas stream might be passed around the bed and not enter into the reaction. However, it can be shown (7) that by-passing would, of itself, cause an apparent decrease in the reaction constant rather than an increase.

It is possible that kinetic effects might be responsible for the increase of specific-reaction constant with gas velocity. It can be shown that if the reduction of nickel oxide were inhibited by the presence of water vapor, the reaction would show a velocity dependence entirely apart from the diffusional factors (7). However, Benton and Emmett (7) observed that when water vapor was added to the hydrogen in the reduction of nickel oxide, the reaction rate was diminished only slightly. The onset of the autocatalytic peak was deferred, but not prevented. It is unlikely that the velocity effect is due solely to purely kinetic causes.

A possible cause for a velocity effect might be that the system was close to equilibrium. If the reaction had reached equilibrium, the specific reaction constant would have varied as the first power of gas velocity. It might be argued that the system was close to equilibrium and that therefore the reaction constant varied as a power of gas velocity less than unity. However, the relative concentrations of water vapor and hydrogen in the gas leaving the system are vastly different from the equilibrium values obtained by a suitable extrapolation of the data of Skapski and Dabrowski (25). It is therefore not possible that the system as a whole was at equilibrium, although it may well be that equilibrium existed at some places in the bed.

Mass-transfer factors are likely causes for the velocity effect observed. The processes previously mentioned as affecting the behavior of this system are the diffusion of reactants through the inert film surrounding the solid particles, the

back diffusion of reaction products through the same film, and the supply of reactants to and removal of products from the region of the bed in which reaction occurred. The papers of Kettering, Manderfield, and Smith (6) and Resnick and White (24) provide means of estimating the variation of mass transfer through the inert film with increased velocity. If this diffusional step is the controlling one, then the mass-transfer coefficients should be of the same order of magnitude as the corresponding specific-reaction constant. Moreover, if the specific-reaction constant and mass-transfer coefficient are both calculated on an area basis, then the value of  $1/k_r'$ , determined from the equation  $1/U'' = 1/k_g' + 1/k_r'$ , should be invariant. In this case,  $1/k_r'$  is taken to represent the sum of all resistances to reaction other than that imposed by diffusion through the inert film. The calculations are summarized in Table 3.

Both sets of calculations show that the resistance imposed by diffusion through the inert film was a negligible part of the total resistance to reaction. Another diffusional or transfer step must be responsible for the observed velocity effect.

**Fluidization.** Toomey and Johnstone (27) have suggested that once a bed is smoothly fluidized, additional gas beyond that required for fluidization is by-passed through the bed. They envisioned that in such a case the fluidized bed would consist of two regions: one, the region of smooth fluidization, in

which the gas flowing through the solid was in viscous flow and the solid particles were close to each other, the second consisting of gas bubbles moving erratically up through the otherwise smooth bed. This behavior is not unlike the action observed in the beds investigated at low temperatures preliminary to these studies. Toomey and Johnstone attributed the violent mixing present in fluid beds to the action of bubbles and conceded that the region immediately adjacent to the gas bubbles was probably highly turbulent. If this is an accurate representation, it is likely that the bulk of the mass transfer which occurs in the bed, and hence the bulk of the reaction, takes place in the highly turbulent region adjacent to the bubbles passing through the smoothly fluidized part of the bed. Toomey and Johnstone indicate that by far the greater portion of the solid in the bed is present in the region of smooth fluidization.

A possible explanation for the abnormally low mass-transfer-per-unit area is that the area involved in such transfer was not the area of all the solid in the bed, but only that of the solid in the region of high turbulence. In this case, the values of  $U''$  shown in Table 3 would be incorrect, since they are based upon the area of all the solid in the bed. The effect of velocity might stem from two causes. First, the increase in velocity must be accompanied by an increase in turbulence and therefore in the area available for mass transfer and reaction. Second, this same increase in turbulence would be expected to improve the mass-transfer coefficient in the turbulent region.

Presumably, the solid in the smoothly fluidized region of the bed reaches equilibrium with the gas passing through that part of the bed, the reaction being controlled by equilibrium for the fraction of gas which passes through the bed. But the major portion of the gas reacted is acted upon in the turbulent zone of the bubbles, and it seems likely therefore that the reaction rate is controlled at least in part by the eddy diffusion through the turbulent zone around the gas bubbles and by the amount of surface made available for mass transfer and reaction because of the turbulence.

No general correlation is attempted here. Too many quantities which should have a place in such a correlation are as yet unmeasured. Among these are the true surface area and surface activity, both assumed to be constant in the preceding calculations, but possibly varying with amount reduced. The size distribution and the nature of the agglomerates which constitute many of the particles must also have an effect. The fraction voids, shape factor, and surface

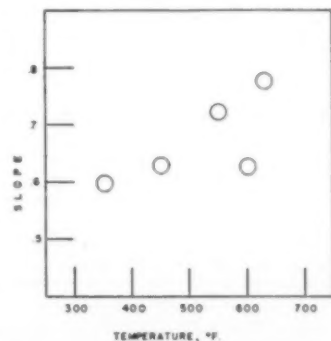


Fig. 9. Variation of  $b$  (slope in Fig. 4) with temperature.

factor, all of which have been found necessary in correlating the pressure drop data for fluid beds, are very likely to be of importance in determining the mass-transfer behavior of a solid-gas fluidized system. The data obtained in connection with this study are by no means sufficient to account for these variables. It should also be stated that the effects herein encountered may be limited to the system studied and the apparatus used.

It has been inferred from the strong temperature variation of the reaction here studied that a kinetic step has a large part to play in the control of the over-all reaction rate. From the variation in the specific-reaction constant at any given temperature with gas velocity, it has been inferred that a diffusional step plays an equally important role in controlling the over-all reaction rate. If both these inferences are true, then as the temperature of reaction rises, the resistance of the kinetic step should become lessened, and the relative importance of the diffusional step in setting the over-all rate should rise. This would be indicated by an increase in the coefficient of  $\log V_L$  in the equation  $\log U = a + b \log V_L$  as the temperature rose. That coefficient is the slope of each of the lines in Figure 4. The slope of each line has been plotted in Figure 9 against the temperature at which the data for that line were obtained. Although the points are such that no quantitative information may be derived therefrom, it is apparent that, qualitatively, the slope rises with increase in temperature. This would appear to substantiate the contention that both the transfer and kinetic steps are of importance in setting the rate in this case.

### Summary

Nickel oxide was reduced with hydrogen in a fluidized bed. The course of the reaction was followed by the change in the hydrogen content of the fluidizing gas mixture between the inlet and outlet of the reactor. Different runs were compared by means of a specific-reaction constant  $U$  calculated on the basis of the weight of oxide available for reduction.

The specific-reaction constant was observed to vary as a function of gas velocity, at constant temperature, and as a function of temperature at constant velocity. At each temperature an equation of the form  $\log U = a + b \log V_L$  was fitted to the experimental points. The coefficient  $b$  was observed to increase with the increase in temperature. At a constant velocity of 1.0 ft./sec., an equation of the form  $\log U = A - (E/2.3R)(1/T)$  was fitted to the data. From the equation, the energy of activation for the over-all reaction was calcu-

lated. It is of the order of magnitude of the energy of activation for the adsorption of hydrogen on metal oxides.

From the foregoing observations, it appears that both the diffusional, or mass-transfer, and kinetic steps are of importance in determining the over-all reaction rate and that the kinetic step which is effective may be the adsorption of hydrogen on nickel oxide.

It was not possible to predict the mass-transfer behavior of this system on the basis of the generalized correlations now available. Because of the nature of the data obtained and their limited quantity, no generalized correlation can be made on the basis of this work.

This process might find industrial use as a means for preparing pure nickel from the oxide. The product at the end of one run was found to be 75% metallic nickel; at that time the bed was still fluidized, and no sticking had been observed.

### Notation

- $a$  = constant in the equation of specific-reaction constant against velocity
- $b$  = constant, coefficient of  $\log V_L$  in equation of specific-reaction constant against velocity
- $k_d$  = diffusional coefficient, moles/hr.(atm.) lb.
- $k_g'$  = diffusional coefficient, moles/hr.(atm.)sq.ft.
- $k_r$  = reaction coefficient, moles/hr.(atm.) lb.
- $k_r'$  = reaction coefficient, moles/hr.(atm.)sq.ft.
- $t$  = temperature, ° F.
- $\tau$  = volumetric flow rate, cu.ft./min. at 32° F. and 1 atm.
- $x_f$  = mole fraction hydrogen in feed
- $x_p$  = mole fraction hydrogen in product
- $A'$  = constant of integration in Arrhenius equation
- $E$  = energy of activation
- $M$  = weight of unreduced oxide at any time, lb.
- $M_0$  = initial weight of oxide charged, lb.
- $M_r$  = weight of oxide reduced during a run, lb.
- $N$  = nitrogen flow rate, moles/min.
- $R$  = universal gas constant
- $R'$  = reaction rate, moles/hr.
- $T$  = temperature, ° R.
- $U$  = specific-reaction constant, moles/hr.(atm.) lb.
- $U'$  = specific-reaction constant, moles/hr.(atm.) (sq.ft.)
- $V_L$  = linear velocity at bed temperature, ft./sec.
- $X_f$  = stoichiometric hydrogen concentration in feed, lb. H<sub>2</sub>/lb. N<sub>2</sub>
- $X_p$  = stoichiometric hydrogen con-

centration in product, lb. H<sub>2</sub>/lb. N<sub>2</sub>

$\theta$  = time of run, hr.

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# RADIATION SHIELDING

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ONE of the biggest problems encountered in the development and use of nuclear energy has been the adequate protection of personnel from radiation. So far most of the work in this field has been carried out by physicists. With the greater participation by engineers in the atomic energy program and the wider industrial use of radioisotopes, it is desirable that engineers have some knowledge of the fundamentals of radiation shielding. This paper covers the main nuclear radiations which are of concern to the engineer.

**Alpha Particles ( ${}^4\text{He}^{+}$ ).** Alpha particles are doubly charged helium nuclei which are ejected in the radioactive decay of heavy elements. Initial energies of alpha particles vary from about 4 to 10 mev\* corresponding to velocities as high as one fourth the velocity of light.

In passing through matter, alpha particles lose energy chiefly by interaction with electrons. Because an alpha particle loses only a small fraction of its energy in a single collision with an electron and is not appreciably deflected by the collision, alpha-particle paths are nearly straight lines. Alphas are the most strongly ionizing of the common radiations.

The penetrating power of an alpha particle is known as its range. This will vary from several centimeters in the case of air to a few thousandths of an inch for a solid material. From the standpoint of radiation shielding, alphas are a negligible external hazard because the common alpha emitters are not sufficiently energetic to penetrate the outer layer of the skin. Most alpha emitters such as radium, uranium and plutonium are serious internal hazards, however, because they accumulate in certain sec-

tions of the body and cause grave local damage.

**Other Heavy Charged Particles.** Light nuclei such as protons, deuterons and tritons are used as bombarding particles in cyclotrons and other types of particle accelerators. Shielding must be supplied for energies as high as several billion electron volts.

Any ion moving at high speed through matter loses its energy by essentially the same mechanism. It can be shown that the rate of energy loss at any given velocity will vary approximately as  $Z^2$ , where  $Z$  is the net charge on the ion. Thus for particles of a given velocity, protons will have the same range as alphas and deuterons will have twice the range of alphas. Even for energies as high as 50 mev, however, the penetration of a proton or deuteron per se is not an important factor in shield design.

The main problem in the shielding of particle accelerators is caused by the production of high energy neutrons through nuclear reactions. Particle energies of about 10 mev exceed the binding energy of neutrons and the latter can be produced from the nuclei present in the accelerators. These neutrons have tremendous penetrating power, and the design of personnel shielding must be based normally on the fast neutron flux.

**Fission Fragments.** Although some fission fragments have energies as high as 100 mev, their charge of about +22 results in a small range. Segre and Wiegand have experimentally measured the penetration of uranium-235 fission fragments, and give values of less than a thousandth of an inch for such metals as aluminum and copper. Thus the aluminum cans used to protect uranium in the pile are of sufficient thickness to stop all fission fragments.

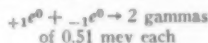
**Beta Particles ( ${}_{-1}e^0$ ).** Beta particles are high-speed electrons or positrons emitted from the nucleus of radioactive isotopes. For energies up to about 1 mev, the interaction of electrons with matter is similar to that of alpha particles since the loss of energy in both processes is through ionization. Since the electrons are much lighter, for a

given energy their velocity is greater and in some cases approaches the velocity of light. Because of this high velocity their specific ionization is less and their range is greater than in the case of alpha particles.

Beta particles are emitted with a continuous spectrum and a beta particle can lose a large fraction of its energy in one collision. These two factors complicate a statistical analysis of the absorption of beta particles, but it has been shown that an exponential absorption law combined with a maximum range is approximately valid. Beta particles are not a serious hazard because they are easily stopped by a thin sheet of aluminum or other solid absorber.

**Positrons ( ${}_{+1}e^0$ ).** Some of the artificially radioactive isotopes decay by the emission of a particle known as a positron which is similar to an electron except that it bears a positive charge. As with negative electrons, positrons are stopped by a thin sheet of aluminum and are not serious hazards.

The main problem with positron emitters is the production of annihilation radiation through the nuclear reaction



This radiation is much more penetrating than the original positrons and must be included in shielding calculations.

**Fast Neutrons ( ${}_0n^1$ ).** Neutrons are uncharged particles of about the same mass as the hydrogen atom. Neutrons given off during fission are emitted with energies as high as several mev. Since neutrons are nonionizing, their penetrating power is high and they cause serious damage to body tissue. For these reasons, neutrons are the most serious radiation hazard encountered in the atomic energy plants.

Fast neutrons, to be stopped, first must be slowed down by collisions with nuclei present in the shield. As a general rule, materials of low atomic weight such as water or paraffin are best for this purpose. This process is known as moderation or thermalizing. Once the neutrons are thermalized, they are

\* In giving the energy of nuclear radiations, it has become standard practice to use the electron volt as a unit. One electron volt is defined as the energy gained by any particle of unit electronic charge in falling through a voltage drop of one volt. For convenience, the kiloelectron volt (kev) and million electron volt (mev) are also used. Thus a particle having an energy of 1 mev is as energetic as the most intense radiation emitted by a million volt x-ray machine.



easily captured by ordinary materials of construction.

**Fission Gammas.** Gamma rays are electromagnetic radiation similar to X-rays but more penetrating. Materials of high atomic weight such as lead are the best shield against gammas. The absorption of gammas by a shield involves several rather complex nuclear reactions but, as a general rule, the intensity of gamma radiation decreases exponentially in passing through a shield. Fission gammas are given off during the splitting of one of the fissionable isotopes, usually uranium-235. The gammas are rather soft, several being obtained for each fission with the total energy about 5 mev.

**Radioactive Decay Gammas.** Most fission products and radioactive isotopes produced in the pile are gamma emitters. Depending on the decay scheme of the isotope in question, gamma energies of several mev may be obtained.

**Inelastic Scattering Gammas.** When fast neutrons are scattered by heavy elements in the shield, part of the neutron energy may appear as gamma radiation. Thus in shielding a neutron emitter, it is not sufficient only to shield the primary source; inelastic scattering will generate gammas in the shield itself and these must be compensated for by additional shielding.

**Capture Gammas.** When neutrons are absorbed by nuclei in the shield, usually one or more gammas are emitted. These capture gammas also are generated in the shield itself and may be treated in the same way as the inelastic scattering gammas.

**Bremsstrahlung.** Depending upon the atomic number of the absorber, higher energy beta particles lose energy in passing through matter by the emission of electromagnetic radiation. This process is analogous to the production of X-rays; the continuous X-ray spectrum given off when beta particles pass through matter is called Bremsstrahlung (braking radiation). In shielding work, Bremsstrahlung are of chief importance in the case of those isotopes which are pure beta emitters, since the Bremsstrahlung produced may be a more serious radiation hazard than the primary

beta particles. They produce a continuous spectrum with a maximum energy equivalent to that of the primary electrons. Depending upon the material irradiated, there will also be sharp peaks superimposed on the continuous spectrum corresponding to the characteristic X-ray levels of the target material. The rate of energy loss by Bremsstrahlung is roughly proportional to the primary energy  $E$  and to  $Z^2$ . It is therefore relatively more important for the heavier elements and for stronger betas.

**Photo-Neutrons.** If beryllium or deuterium is present in the shield, it is possible for higher energy gammas to react with the nuclei of these atoms to eject neutrons known as photo-neutrons. This complicates the shielding problem because it leads to a secondary source of neutrons in the shield itself and requires the placing of neutron absorber in the outer layers of the shield.

### Acknowledgment

The author wishes to thank E. P. Blizard, head of the shielding group at Oak Ridge National Laboratory, for making available Figure 1, Genealogy of Radiations for Shielding.

### Example

As an example of radiation shielding, let us consider the problem of shielding a nuclear chain reactor. Suppose that a university is to install a small enriched uranium, water-moderated, thermal reactor. Reactor fuel elements are of aluminum, and

shielding is to be provided by ordinary concrete. Total power is 10 kw. What radiations must be stopped by the concrete?

The fission of one atom of uranium-235 leads to an energy release of about 200 mev. By using the conversion factors 1 mev =  $1.6 \times 10^{-6}$  erg and 1 w. =  $10^7$  erg/sec., we find that a power of 1 w. requires  $3.1 \times 10^{10}$  fissions/sec. Thus a power of 10 kw. is equivalent to  $3.1 \times 10^{11}$  fissions/sec. of uranium-235. Distribution of fission energy is given in Table 1.

TABLE 1.—DISTRIBUTION OF FISSION ENERGY

	mev/fission
Kinetic energy of fission fragments....	163
Kinetic energy of neutrons .....	3
Prompt gammas .....	5
Gamma decay of fission fragments ....	6
Beta decay of fission fragments .....	5
Neutrino energy .....	10
Total .....	191

There are four other sources of gamma energy which must be included. About 16% of the captures of a neutron by uranium-235 are nonfission captures leading to the formation of uranium-236 and the evolution of gamma energy. The spectrum of these uranium-235 capture gammas is not known, but it can be assumed that two 3-mev photons are produced per capture. Hydrogen of the water moderator will capture neutrons, each capture leading to the evolution of one 2.2-mev gamma. Aluminum also captures neutrons, in this case emitting a complex gamma spectrum with a total energy of about 7 mev and a most probable energy of about 3.5 mev. Neutrons leaking out into the shield are slowed down and finally captured by the concrete to generate capture gammas of variable energy in the shield proper.

Since the penetrating power of fission fragments and beta particles is small, they are neglected in most shielding calculations. If the compositions and relative amounts of all the materials present in the reactor are known, the production of gammas by the various mechanisms can be calculated. Table 2 gives representative values of the radiations encountered in a reactor of this type. The problem of radiation shielding is to reduce the intensity of this radiation to the tolerance level of a few hundred particles/(sq.cm.) (sec.) at the outside surface of the shield. In some shielding problems, the original intensity of the radiation must be reduced by a factor of as much as  $10^9$ .

(Presented at A.I.Ch.E. Forty-fourth Annual Meeting, Atlantic City, N. J.)

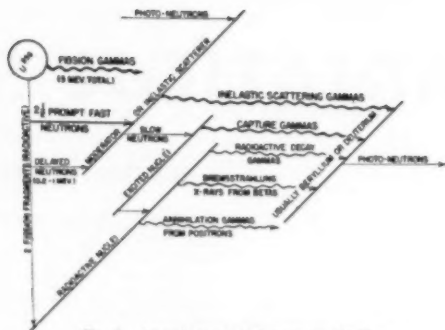


Fig. 1. Genealogy of radiations for shielding.

TABLE 2.—GAMMA AND NEUTRON EMISSION FROM 10-KW. REACTOR

	No./sec.	Avg. Particle Energy
Prompt gammas .....	$1.55 \times 10^{12}$	1 mev.
Fission product gammas .....	$1.24 \times 10^{12}$	1.5
Uranium capture gammas .....	$1.14 \times 10^{11}$	3
Aluminum capture gammas .....	$5 \times 10^{10}$	3.5
Water capture gammas .....	$8 \times 10^{10}$	2.2
Concrete capture gammas .....	$1 \times 10^{11}$	Variable
Fast neutrons .....	$1 \times 10^{11}$	1
Slow neutrons .....	$2 \times 10^{11}$	1/30 ev

# VAPORIZATION RATES AND HEAT-TRANSFER COEFFICIENTS

## For Pure Liquid Drops

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Vaporization rate data and surface-temperature data were obtained for nine pure liquids evaporating from the surface of a porous sphere, and experimentally evaluated heat-transfer coefficients were found to correlate a semiempirical equation that expresses the Nusselt number for heat transfer as a function of a new dimensionless number,  $Re \cdot Sc$ , and the thermal conductivity ratio,  $k_a/k_l$ .

Surface temperatures determined for the nine pure liquid drops, namely, nitrobenzene, *n*-octane, benzene, methanol, acetone, water, ethanol, butanol, and carbon tetrachloride, were found to be approximately equal to wet-bulb temperatures. A new method of predicting wet-bulb temperatures from boiling-point data and wet-bulb data for water was developed.

THE design of high-output combustors for jet-propelled aircraft and such equipment as spray dryers and cooling towers requires an accurate knowledge of liquid vaporization rates. According to the type of equipment, the liquid may evaporate from spheres, cylinders or flat surfaces. In jet engines, the fuel is frequently injected as liquid droplets at a point upstream of the combustion zone, and the concentration of vaporized fuel in the fuel-air stream entering this zone is determined by the rate of evaporation of the droplets. To determine this evaporation rate, a study was made of droplets vaporizing under conditions similar to those encountered in aircraft combustion systems.

The two general methods of calculating the vaporization rate of a pure liquid drop are: (1) methods using the difference between the partial pressure of the vapor at the drop surface and the partial pressure of the vapor in the streaming air as the driving potential; and (2) methods using corresponding temperature differentials that appear as the driving potential in the heat-balance equation. Using the first method, Sherwood and Williams (6) recommend the following vaporization-rate equation for three ranges of Reynolds number:

$$\frac{dm}{d\theta} = \frac{p_c M P}{RT p_{hm}} D_c \pi n Nu'$$

† Lewis Flight Propulsion Laboratory.

$$Nu' = 2, \text{ when } Re < 4$$

$$Nu' = 1.50 Sc^{1/4} Re^{0.25}$$

$$\text{when } 4 < Re < 400$$

$$Nu' = 0.43 Sc^{1/4} Re^{0.56}$$

$$\text{when } Re > 400$$

Also using the first method, Frössling (1) presents the equation:

$$\frac{dm}{d\theta} =$$

$$\frac{p_c M}{RT} \frac{P}{p_{hm}} D_c \pi n (2 + 0.552 Sc^{1/4} Re^{1/2})$$

for all Reynolds number values and an air temperature of 20° C.

Consideration of the applicability of the above mass-transfer equations to vaporization in high temperature air streams shows that  $p_{hm}$  has a large effect on vaporization rates inasmuch as it varies markedly with small changes in the surface temperature of the drop. An accurate determination of surface temperatures is therefore required to apply mass-transfer equations to vaporization calculations for high air temperatures. This evaluation becomes increasingly difficult as air temperatures are increased. For the second general method, however, the driving potential may be approximated by the difference between the air temperature and the boiling point of the liquid, and an accurate determination of surface temperature is not required in the case of high air temper-

atures. Thus, a heat-balance equation which would show the effect of molecular mass transfer on the heat-transfer coefficient was chosen for investigation.

### Procedure

**Experimental.** The apparatus used to determine vaporization rates of pure liquid drops is shown in Figure 1. Air was supplied from the central laboratory system at 50 lb./sq. in. gage and 16% relative humidity. The air was metered by a rotameter, and the temperature was controlled over a range of 80° to 1000° F. by an electric air heater. Air leaving the heater passed through an insulated 1-in. pipe and into a 3-in. diam. calming chamber containing two sections of 200-mesh screen placed normal to the air stream. The calming section was used to produce an air stream with low turbulence and flat velocity profile. The velocity profile showed velocity variations of less than 10% for points up to 1/4 in. of the wall of the test section. The sphere was placed at a depth of 1 in. from the open end and 1/2 in. from the wall of the 2-in.-diam., 6-in. long test section. The air temperature was measured by a thermocouple mounted in the same plane as the vaporization sphere.

The surface temperature of each liquid drop for the range of inlet temperature studied was obtained with a fine thermocouple junction of 40-gage iron-constantan wire flush with the surface of the sphere. A thermocouple element was also placed in the center of the sphere to determine the rate at which sensible heat of the liquid was transferred to the drop, during the run, and to show the effect of the core temperature on the surface temperature of the drop.

The liquid feed system consisted of a syringe, hypodermic needle, and cork sphere mounted on the end of the hypodermic needle. Three spheres having an average diameter of 0.688 cm. were used during the experiment. The spheres were constructed of selected cork free of coarse grains and piths, and the porosity of each was adjusted by piercing the sphere with a fine needle.

Vaporization rates were measured directly by weighing the unit shown in Figure 2 on an analytical balance before and after each vaporization run. The technique employed consisted in:

1. Removing the test tube from the unit
2. Holding the sphere in the air stream for two minutes
3. Replacing the test tube over the sphere.

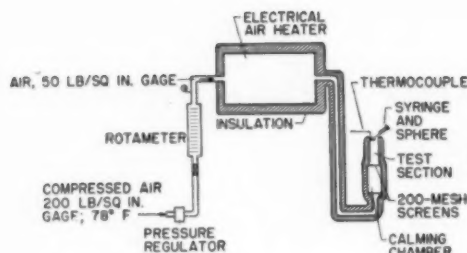


Fig. 1. Schematic diagram of vaporization equipment.

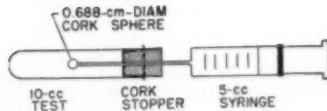


Fig. 2. Vaporization unit.

Results from the use of this equipment showed that vaporization data were reproducible within  $\pm 5\%$  when the following conditions were fulfilled:

1. Air temperatures varied less than  $2^\circ\text{F}$ .
2. A cork stopper was inserted in the open end of the test tube during the 2-min. vaporization run.
3. Pressure was applied evenly to the syringe and the unit was slowly rotated to keep the surface of the sphere thoroughly wet.
4. Not more than 1 sec. was taken to transfer the sphere from the test tube to the air stream or to accomplish the reverse procedure.

**Calculations.** The physical properties  $H_v$ ,  $k$ ,  $\rho$ , and  $\mu$  that were used in calculations were obtained from Lange's Handbook (3) and Perry's Handbook (5). The molecular mass diffusivity  $b_{av}$  was calculated from the expression

$$b_{av} = \frac{PM}{RT_{av}} D_v$$

where

- $P$  = total pressure, atmospheres
- $M$  = molecular weight of diffusing vapor
- $R$  = universal gas constant 82.0 (atm.) (cc.)/( $^\circ\text{K}$ .) (mole)
- $T_{av}$  = average film temperature,  $^\circ\text{K}$ .
- $D_v$  = volume diffusivity as defined by Gilliland (2)

**Range of Conditions.** Data on vaporization rates were taken at a constant inlet-air temperature of  $28^\circ\text{C}$ . and varying air mass flow for a single liquid, and at constant air mass flow with air temperatures varying from  $30^\circ$  to  $500^\circ\text{C}$ . for nine pure liquids. Surface-temperature data were taken over the same air-temperature range for the nine liquids referred to in Abstract.

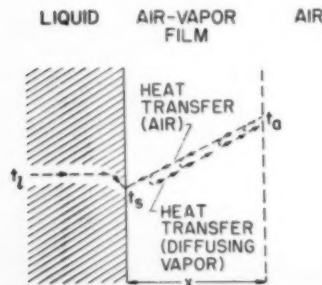


Fig. 3. Schematic representation of a liquid vaporizing in an air stream.

## Results and Discussion

A drop vaporizing in an air stream is pictured in Figure 3 as being surrounded by a vapor film. The heat balance for this system can be expressed

$$h'A(t_a - t_s) = \frac{dm}{d\theta} [H_v - c_p(t_i - t_s)] \quad (1)$$

where  $h'$  is the heat-transfer coefficient evaluated at the liquid-vapor interface. In this investigation,  $c_p(t_i - t_s)$  is small compared with  $H_v$ , and it is possible to rewrite the equation

$$h'A(t_a - t_s) = \frac{dm}{d\theta} H_v \quad (2)$$

When the heat-transfer coefficient is evaluated at the vapor-air interface as shown in Figure 3, the heat balance may be written

$$hA(t_a - t_s) = \frac{dm}{d\theta} H_v \quad (3)$$

where  $h$  is a function of the heat transferred by the air and the diffusing vapor as a result of collisions between vapor and air molecules.

There are three types of bimolecular collision that may occur in a binary mixture of vapor and air surrounding the vaporizing drop. They may be defined as collisions between: (1) two air molecules, (2) two vapor molecules, or (3) an air and a vapor molecule. When two air molecules collide, heat is transferred from the warmer molecule near the air stream to the cooler molecule that is closer to the sphere's surface. As a net result of collisions between air molecules, heat is conducted across the film to the sphere's surface and can be expressed as a function of the thermal conductivity of air  $k_a$ . When two vapor molecules collide, this heat transfer, which may be expressed as a function of the thermal conductivity of the vapor  $k_v$ , has no appreciable effect on heat transferred to the sphere's surface because a net diffusion of vapor molecules into the air stream occurs. In collisions between an air and vapor molecule, heat is transferred from air to vapor mole-

cules that conduct heat from the film as shown in Figure 3. This heat transfer can be expressed as a function of the ratio  $k_a/k_v$ . The film coefficient  $h$  may be expressed as a function of  $k_a$  and the thermal-conductivity ratio  $k_a/k_v$ .

Because the film coefficient for vaporization must also be a function of momentum and mass-transfer groups, that is, the Reynolds and Schmidt numbers, the Nusselt number for an air-vapor film may be expressed as

$$\frac{hd}{k_a} = f\left(\frac{k_a}{k_v}\right)^m (Re)^n (Sc)^p + \frac{d}{x} \quad (4)$$

where  $f$  is a proportionality constant,  $d/x$  the Nusselt number for still air, and  $x$  the film thickness.

Data for heat transfer between spheres and air streams have been correlated by Williams (4), and the equation

$$\frac{hd}{k_a} = f(Re)^n = 0.33(Re)^{0.66} \quad (5)$$

was obtained for a Reynolds number range of 20 to 150,000. Equation (4) was derived for an air-vapor film and reduces to Equation (5) when a pure air film is considered. If Equation (4) is applied to the range of conditions investigated by Williams, i.e., a solid sphere suspended in an air stream, the still air Nusselt number  $d/x$  is relatively small and may be neglected. The thermal conductivity ratio for a pure air film is unity, and the Schmidt number is also equal to unity since kinetic theory of gases defines the viscosity of air as the mass diffusion coefficient for air molecules diffusing through air, i.e.,  $\mu = b_{av}$ .

Williams' correlation included one case of simultaneous heat and mass transfer, namely, Vydrov's data for ammonia vapor diffusing through an air-ammonia film. Since the thermal conductivity of ammonia vapor is nearly the same as that of air, the ratio  $k_a/k_v$  may be taken as unity. Also, the Schmidt number for this case is approximately equal to unity. Thus, one would expect the Williams equation to hold fairly well for Vydrov's data.

A series of runs was made for one fluid in which mass-air-flow rates were varied and the air temperature was held constant,  $((k_a/k_v)(Sc) = \text{constant})$ .

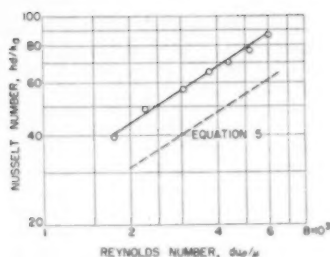


Fig. 4. Correlation of heat- and mass-transfer data for 0.688 cm.-diam. methyl alcohol drop in 28°C. constant-temperature air stream, and variable air-mass-flow rate of 75 to 263 lb./hr.

Data for these runs are plotted in Figure 4. This plot shows  $n = 0.6$  or

$$\frac{hd}{k_a} = f(Re)^{0.6}(Sc)^p \left( \frac{k_a}{k_v} \right)^m + \frac{d}{x} \quad (6)$$

Equation (5) is also plotted in Figure 4 to show the Nusselt number is higher for an air-methanol vapor film than it is for a monomolecular film having a thermal conductivity ratio and Schmidt number of unity.

In Equation (6), both  $Sc$  and  $k_a/k_v$  are functions of air temperature and the vapor properties. It is difficult, therefore, to vary either  $Sc$  or  $k_a/k_v$  independently as functions of the film coefficient. A correlation was undertaken using a new number  $(Re \cdot Sc)$ , which is defined as the ratio of turbulent momentum transfer to molecular mass transfer. This new correlative number is comparable to the Peclet number used in heat-transfer studies.

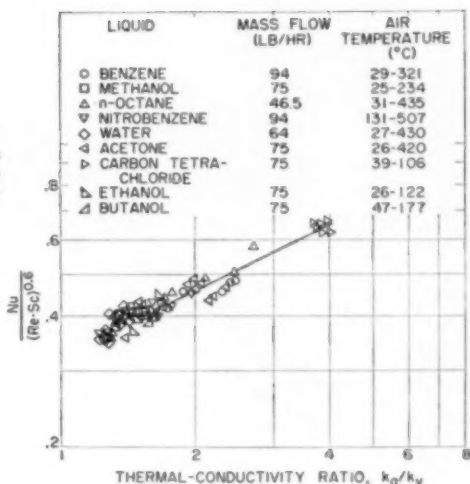
By substituting  $(Re \cdot Sc)^{0.6}$  for  $(Re)^{0.6} \cdot (Sc)^p$ , Equation (6) can be rewritten

$$\frac{hd}{k_a} = f(Re \cdot Sc)^{0.6} \left( \frac{k_a}{k_v} \right)^m + \frac{d}{x} \quad (7)$$

because  $hd/k_a$  must still be a function of  $Re^{0.6}$ . To verify this relation and to evaluate  $m$ , vaporization tests were made in which the mass-air-flow rate was held constant and the air temperature was varied. Vaporization data for nitrobenzene, *n*-octane, benzene, methanol, acetone, water, ethanol, butanol, and carbon tetrachloride are given in a logarithmic plot of  $hd/k_a(Re \cdot Sc)^{0.6}$  against  $k_a/k_v$  for the nine liquids as shown in Figure 5. From this straight-line plot, it is evident that  $(Re \cdot Sc)^{0.6}$  correlates the data and  $m = 0.5$ ; or

$$\frac{hd}{k_a} = f(Re \cdot Sc)^{0.6} \left( \frac{k_a}{k_v} \right)^{0.5} + \frac{d}{x} \quad (8)$$

Fig. 5. Correlation of heat- and mass-transfer data with thermal conductivity ratio  $k_a/k_v$ .



A plot of  $hd/k_a$  against  $(Re \cdot Sc)^{0.6} (k_a/k_v)^{0.5}$  on rectangular-coordinate graph paper in Figure 6 shows that the equation for the film coefficient of a pure liquid drop vaporizing in an air stream may be written

$$\frac{hd}{k_a} = \left[ 2 + 0.303(Re \cdot Sc)^{0.6} \left( \frac{k_a}{k_v} \right)^{0.5} \right] \quad (9)$$

for the conditions covered in this investigation. Data in Figure 6 show  $d/x_a = 2$  for vaporization in quiescent air and the constant  $f = .303$  which is approximately ten per cent less than the value  $f = .33$  obtained by Williams for heat transfer.

Data were taken for various feed temperatures to check the effect of the sen-

sible heat of the liquid on the vaporization rate, and the effect of feed temperatures on surface temperatures. The fact that no consistent trends of feed temperature were observed verified the assumption of negligible effect of the liquid feed temperature on the experimental film coefficient.

By substituting the value of  $h$  in Equation (9) into the heat-balance Equation (3), the vaporization rate of a pure liquid drop may be expressed

$$\frac{dm}{dt} = \frac{k_a \Delta T}{H_v} \pi d \left[ 2 + 0.303(Re \cdot Sc)^{0.6} \left( \frac{k_a}{k_v} \right)^{0.5} \right] \quad (10)$$

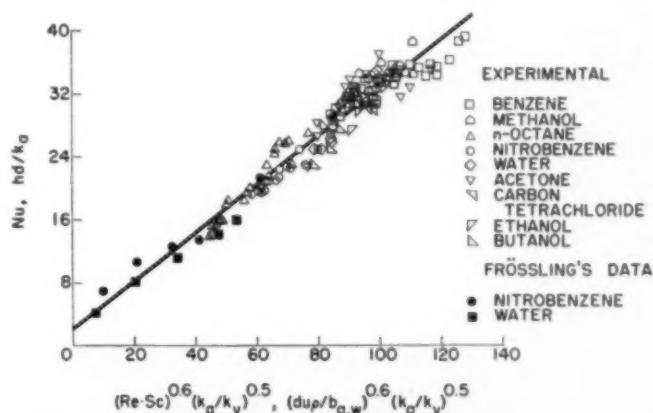


Fig. 6. Correlation of Nusselt number with  $k_a/k_v$  and  $Re \cdot Sc$ .

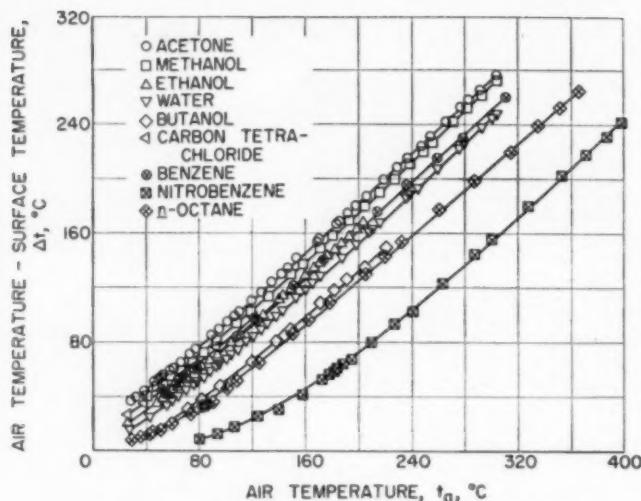


Fig. 7. Psychrometric plot of driving force  $\Delta t$  for nine pure liquids.

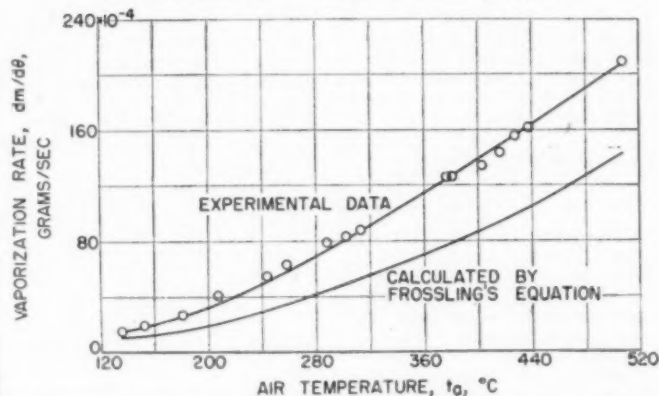


Fig. 8. Comparison of experimental vaporization rates for nitrobenzene drops in varying air-stream temperature with rates calculated by Froßling's equation (2). Air-mass-flow rate, 94 lb./hr.; experimental Reynolds number range 1610 to 1030.

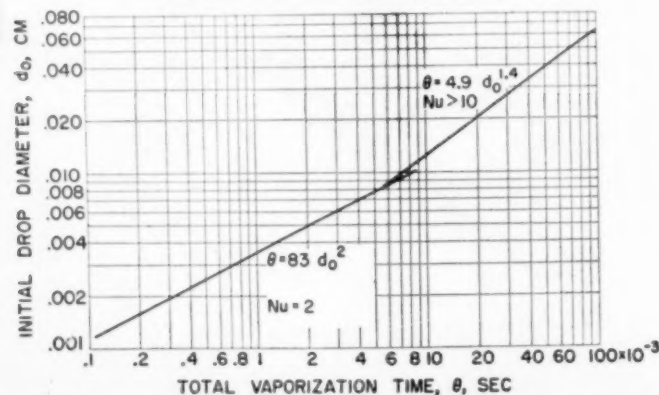


Fig. 9. Chart for determining vaporization time for *n*-octane droplet of initial diameter,  $d_o$ . Conditions:  $t_a = 680^\circ \text{C}$ ;  $u_a = 30.5 \text{ m./sec.}$ ;  $\Delta t = 555^\circ \text{C}$ .

Surface temperatures measured in this experiment and shown as psychrometric plots in Figure 7 were compared with wet-bulb temperatures ( $t_w$ ) and were found to agree within 5% of these values for carbon tetrachloride, benzene, and water.

To compare values of  $dm/d\theta$  obtained in this experiment with values calculated from Equation (10), a plot of  $dm/d\theta$  against air temperature for nitrobenzene is shown in Figure 8. Values of  $dm/d\theta$  calculated by Froßling's equation are also shown in this figure, and agree fairly well with experimental data at room temperatures but are invalid at elevated air temperatures.

To determine the time required for a droplet of a given diameter to vaporize completely, Equation (10) may be re-written

$$\frac{\rho_l H_v}{4k_a \Delta t} = \frac{d \cdot d(d)}{\left[1 + 0.152(Re \cdot Sc)^{0.6} \left(\frac{k_a}{k_v}\right)^{0.5}\right]} \quad (11)$$

and integrated to give total vaporization time  $\theta$  as a function of the initial diameter  $d_o$ ; or

$$\theta = \frac{\rho_l H_v}{4k_a \Delta t} \frac{d_o^{1.4}}{0.213 \left(\frac{\mu \rho}{\theta_{\theta, w}}\right)^{0.6} \left(\frac{k_a}{k_v}\right)^{0.5}} \quad (12)$$

for values of  $Nu > 10$ ; and

$$\theta = \frac{\rho_l H_v}{4k_a \Delta t} \frac{d_o^2}{2} \quad (13)$$

for values of  $Nu = 2$ . A plot of equations (12) and (13) is shown in Figure 9 for *n*-octane at  $t_a = 680^\circ \text{C}$ ,  $u_a = 3050 \text{ cm./sec.}$ , and  $\Delta t = 555^\circ \text{C}$ . The applicability of Equation (10)

$$\frac{dm}{d\theta} = \frac{k_a \Delta t}{H_v} \pi d N_u$$

may be considerably extended by approximating  $\Delta t$  from boiling-point data instead of relying on the availability of wet-bulb-temperature data. The psychrometric chart in Figure 7 shows that  $\Delta t$  is a function of the boiling point of the liquid. A plot of  $t_{a,1}$  against  $t_{a,w}$  for constant  $\Delta t$  values was made, and is shown in Figure 10.

A straight-line plot for each liquid is comparable to Dühring lines used in vapor-pressure determinations. The intercept of the ordinate axis  $t_{a,w}$  was then evaluated as  $K$  and plotted against the boiling point of each liquid, as shown in Figure 11.



Equations for the plots in Figures 10 and 11 may be written

$$t_{a,w} = t_{a,i} + K$$

and

$$K = -0.80 t_{B.P.} + 75$$

and may be combined to give the equation

$$t_{a,w} = t_{a,i} - 0.80 t_{B.P.} + 75 \quad (14)$$

where  $t_{B.P.} = 94^\circ \text{C.}$  for the faired value of water.

This equation may be readily used to approximate the surface temperature of a drop from a plot of  $\Delta t$  against  $t_a$  for water if the air temperature and the boiling point of the liquid drop are known.

**Sample Calculation.** To determine  $\Delta t$  for a liquid having a boiling point of  $80^\circ \text{C.}$  and suspended in a  $250^\circ \text{C.}$  air stream, these values are substituted in Equation (14)

$$t_{a,w} = t_{a,i} - 0.80 t_{B.P.} + 75$$

$$t_{a,w} = 250 - (0.80)(80) + 75 = 261^\circ \text{C.}$$

The plot of  $t_a$  against  $\Delta t$  for water in Figure 7 shows that when  $t_a = 261^\circ \text{C.}$ ,  $\Delta t = 208^\circ \text{C.}$ , which is the  $\Delta t$  value for a liquid having a boiling point of  $80^\circ \text{C.}$  As a check on the equation, the plot of benzene, which has a boiling point of  $80^\circ \text{C.}$  in Figure 7 shows that  $\Delta t = 206^\circ \text{C.}$  in a  $250^\circ \text{C.}$  air stream. For this condition, the method of determining  $\Delta t$  with Equation (14) agrees with the experimental value within 1 per cent.

### Conclusions

An analysis of the effect of elevated air temperatures on the rate of evaporation of a pure liquid drop based on a heat-balance concept resulted in the semiempirical equation:

$$\frac{dm}{dt} =$$

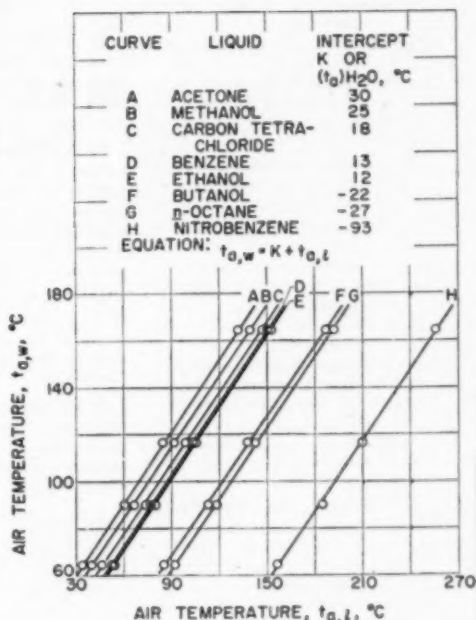
$$\frac{k_a \Delta t}{H_v} \pi d \left[ 2 + 0.303 (Re \cdot Sc)^{0.5} \left( \frac{k_a}{k_v} \right)^{0.5} \right]$$

Experimental data over an air-temperature range of  $30^\circ$  to  $500^\circ \text{C.}$  for nine pure liquids having latent-heat values ranging from 50 to  $500 \text{ g.-cal./g.}$  were used in developing this equation.

### Notation

- $A$  = area of drop, (sq.cm.)
- $b_{g,w}$  = molecular mass diffusivity, (g./cm.) (sec.)
- $c$  = specific heat, (g.-cal./g.) ( $^\circ \text{C.}$ )
- $d$  = drop or sphere diameter, (cm.)
- $D_g$  = volumetric diffusion coefficient or diffusivity, (sq. cm./sec.)

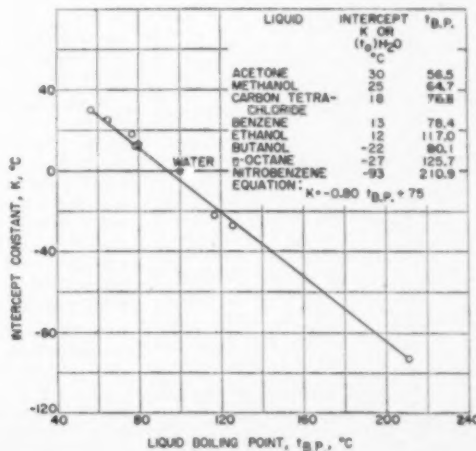
Fig. 10. Cross-plot of Fig. 7 obtained at constant  $\Delta t$  values  $> 40^\circ \text{C.}$



- $dm/d\theta$  = vaporization rate, (g./sec.)
- $f$  = proportionality constant
- $h$  = heat-transfer coefficient at air-vapor interface, (g.-cal./g.-cal./g. (sec.) (sq.cm.) ( $^\circ \text{C.}$ ))
- $h'$  = heat-transfer coefficient at liquid-vapor interface, (g.-cal./g.-cal./g. (sec.) (sq.cm.) ( $^\circ \text{C.}$ ))

- $H_v$  = latent heat of vaporization, (g.-cal./g.)
- $k$  = thermal conductivity evaluated at  $t_{a,w}$ , (g.-cal./g.-cal./g. (sec.) (sq.cm.)
- $K$  = intercept constant, ( $^\circ \text{C.}$ )
- $K_m$  = mass-transfer coefficient, (g./g.-cal./g. (sec.) (sq.cm.)
- $M$  = molecular weight of vaporizing liquid

Fig. 11. Correlation of psychrometric data with boiling points.



$m$  = quantity of material vaporized, (g.)  
 $Nu$  = Nusselt group for heat transfer,  $(hd/k)$   
 $Nu'$  = Nusselt group for mass transfer,  $(K_m d/b_{gw})$   
 $P$  = total pressure, (atm.)  
 $p_v = (p_{v,2} - p_{v,1})$ , difference between partial pressure of vapor at drop surface (approximately saturation pressure) and partial pressure of vapor in streaming air, (atm.)  
 $p_{bm}$  = log mean pressure of inert or nondiffusing gas (atm.)  
 $Pe$  = Peclet number,  $(Pr \cdot Re, dup/k)$   
 $Re$  = Reynolds number based on drop diameter  $d$ ,  $(dup/\mu)$   
 $Re \cdot Sc$  = new correlative group,  $(dup/b_{gw})$   
 $Sc$  = Schmidt group based on mass diffusivity of vapor  $(\mu/b_{gw})$   
 $t_{av}$  = average film temperature, ( $^{\circ}C$ )  
 $t_{a,l}$  = air temperature at which liquid has same  $(t_a - t_s)$  value as water  
 $t_{a,w}$  = air temperature at which water has same  $(t_a - t_s)$  value as given liquid  
 $\Delta t$  = difference between air temperature and surface temperature of drop, ( $^{\circ}C$ )  
 $u$  = velocity of air, (cm./sec.)  
 $x$  = film thickness, cm.  
 $\theta$  = vaporization time, (sec.)  
 $\mu$  = gas viscosity, (g./sec. (cm.))  
 $\pi$  = constant, (3.1416)  
 $\rho$  = gas density, (g./cc.)  
 $\rho_l$  = liquid density, (g./cc.)

#### SUBSCRIPTS:

$a$  = air  
 $B.P.$  = boiling point  
 $l$  = liquid  
 $o$  = initial condition  
 $s$  = surface  
 $v$  = vapor  
 $w$  = water

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#### Discussion

**C. R. Wilke** (University of California, Berkeley, Calif.): Did you find it necessary to correct your heat-transfer coefficients for radiation for the conditions under which you were operating?

**R. D. Ingebo:** No. The tests performed in the standard 2-in. black iron pipe were compared with tests using a polished aluminum tube inserted inside the pipe, and no effect of radiation from the wall on evaporation rates or surface temperatures was observed.

**R. S. Fein** (The Texas Co., Beacon, N. Y.): Have you made any investigations on the variation in composition through the vapor film, fuel-air ratios, for instance?

**R. D. Ingebo:** No. Data of this nature would be difficult to obtain under the conditions of this investigation since maximum film thicknesses were approximately 0.3 mm.

**A. P. Colburn** (University of Delaware, Newark, Del.): In the case of simultaneous heat and mass transfer, I think we have been fairly careless generally in not considering the effect of one of the processes on the other in a theoretical way. In a paper by Tom Drew and myself for the Institute in 1936, we presented the mathematics that are involved which had been published practically simultaneously by Ackerman, in *Forschung* magazine of that year. It turns out that as vapor molecules are diffusing through the film, they give up or absorb heat of a sensible nature and, therefore, distinctly change the rate of sensible heat transfer. This is a rather complicated matter, but fortunately we were able to present a simple curve that relates the sensible heat-transfer coefficient to the rate of vapor transfer.

Now, if you were to involve that relationship, you might find that it would take care of a factor that resulted in your bringing in the thermal conductivity ratio.

**R. D. Ingebo:** The ratio of the thermal conductivity of air to that of the diffusing vapor was used in this investigation as a means of evaluating the effective thermal conductivity of a bimolecular film containing a vapor diffusing through an air film. It may be possible that an evaluation of film properties from the standpoint of sensible heat transferred by the diffusing vapor would yield somewhat similar results.

**H. D. Evans:** (Shell Development Company, Emeryville, Calif.): A thermocouple, no matter how small it might be, is still large compared with the molecular layer along the surface of the drop. Is it not possible that the actual surface temperature may be different

from the value measured by the thermocouple, which may be a thousand molecules inside the surface.

**R. D. Ingebo:** If you remember, I stated that I controlled the liquid temperature of the drop fairly close to that of the surface temperature. Thus, it was possible to obtain fairly accurate surface temperatures.

**C. F. Oldershaw** (The Dow Chemical Co., Pittsburg, Calif.): I would expect that it would be very difficult to obtain accurate measurements of the surface temperatures of the small porous spheres due to conductivity and radiation effects. Would you therefore explain what precautions were taken to insure that the temperatures measured by the thermocouple were the actual surface temperatures?

**R. D. Ingebo:** The technique of maintaining the liquid core temperature near the surface temperature and using a fine thermocouple element made it possible to obtain accurate liquid surface temperatures in relatively high-temperature air streams. The possibility of the thermocouple junction being partially exposed to the air stream and recording erroneously high temperatures was avoided by keeping the thermocouple element submerged in the thin liquid film surrounding the sphere. This technique required considerable care at high temperatures and may not yield accurate results if applied to extreme temperature conditions beyond the range of this investigation.

**C. E. Dryden** (Battelle Memorial Institute, Columbus, Ohio): The title of your paper is, "Vaporization from Pure Liquid Drops." Actually vaporization was from the surface of porous spheres. Thinking about the previous talk, how would vaporization rates from pure liquid drops compare with your data? Would there be any difference due to circulation or other phenomena within a pure liquid drop, which was not present in a porous sphere?

**R. D. Ingebo:** The materials evaporated in these tests were pure liquids, and a constant surface area was maintained by use of a porous solid conforming to the shape of a spherical drop. An investigation has been reported by Powell showing vaporization rates to be the same for liquid drops and wetted spherical surfaces. Also, my data were found to correlate those of Frössling who used free-falling drops. The effect of circulation in the liquid film surrounding the sphere was checked by rotating the sphere at different speeds, but no effect of circulation was noted.

(Presented at A.I.Ch.E. Forty-fourth Annual Meeting, Atlantic City, N. J.)

# A LIQUID-DOWTHERM HEATING AND COOLING UNIT

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A highly effective installation to maintain reaction temperatures in pilot-scale equipment has been designed and constructed for operation over a temperature range of 125°-650° F. Dowtherm A in the liquid state is the heat-transfer medium employed in essentially independent heating and cooling systems. Reaction temperatures can be controlled automatically at the user by blending a regulated stream of hot Dowtherm with a constant amount of cold Dowtherm.

The temperatures of the hot and cold Dowtherm streams are maintained respectively by a gas-fired heater and a water-cooled exchanger. Centrifugal pumps provide forced circulation through the systems. Safety devices automatically shut down the unit if the control instruments malfunction or the utilities fail.

Operating experience with this installation over a period of three years has demonstrated that temperatures in the range of 200°-550° F. can be controlled to within one per cent.

IN the design of pilot-plant equipment a problem, often encountered, is that of rapidly heating and cooling process vessels. If a number of adjacent kettles, reactors or other users are to be operated over approximately the same temperature ranges, it is usually desirable to manifold them to common heating and cooling systems. Media frequently employed are the liquid and vapor phases of water or organic compounds (4). Dowtherm (2) is a commonly used organic heat-transfer material which, for heating purposes, is generally employed in the vapor phase to take advantage of the latent heat of vaporization (1). However, vapor is not well suited to the control by cooling of exothermic reactions, and installations utilizing vapor require either gravity or forced return of condensate to the vaporizer (3). Gravity return of condensate requires a substantial difference in elevation between user and vaporizer; forced return necessitates the installation of a pump at each user and thereby increases maintenance problems.

In the authors' laboratory the specific requirement was to heat and cool rapidly a number of users over a temperature range of 125° to 650° F. The disadvantages of vapor-phase operation led to the design and installation of a liquid-phase heating and cooling unit employing Dowtherm A (5, 6).

## Description of Equipment

The unit consists of essentially independent heating and cooling systems arranged to permit simultaneous operation of a number of users at different temperatures. Restriction orifices located in the distribution headers of both the hot and cold systems maintain a pressure differential between the supply and return lines. The process vessels are connected in parallel between the lines and are manifolded to both systems (Fig. 1). Hot Dowtherm to the users is controlled automatically. The cold Dowtherm is controlled manually.

The principal items of equipment are the Dowtherm storage and expansion tanks, hot and cold pumps, heater, cooler, temperature-control instruments and valves, and safety devices. Partial specifications for four major equipment items are presented in Table I.

The shell-and-tube heater supplies Dowtherm at temperatures from 325° to 650° F. It will furnish 300,000 B.t.u./hr. while heating Dowtherm from 600° to 656° F., and will operate satisfactorily at a minimum demand of 25,000 B.t.u./hr. Fuel gas at a pressure of 8 in. of water is supplied through five burners, each 5 in. in diam., and a ring-type pilot burner 13 in. in diam. The hot combustion products pass through the heater tubes and vent through a 10-in. stack, on which is installed a draft hood.

Dowtherm circulating in the cooling system passes through a water-cooled exchanger consisting of three fin-tube sections arranged in series to give a total area of 78 sq. ft. The exchanger will remove 100,000 B.t.u./hr. while cooling 10,000 lbs./hr. of Dowtherm from 150° to 125° F., with inlet and outlet cooling-water temperatures of 75° and 85° F., respectively.

Both hot and cold Dowtherm are circulated by means of centrifugal pumps driven by 3-hp. motors. Both pumps deliver 30 gal./min. at 1800 rev./min., with suction and discharge pressures of 50 and 80 lbs./sq.in. gage, respectively. Because of the high operating temperatures encountered, the hot pump is constructed of steel. The shaft on the hot pump is sealed with a packed gland consisting of one ring of laminated aluminum, several rings of metallic-faced packing, a lantern ring, and several more rings of metallic-faced packing. The seal is cooled by circulating a small amount of Dowtherm from the cold pump through the lantern ring.

The Dowtherm storage tank, 3 ft. in diam. and 6 ft. long, has a capacity of 355 gal. and normally operates at atmospheric pressure and room temperature. Relief valves located throughout the Dowtherm system discharge into a common header, which drains into this tank. The expansion tank, 2 ft. in diam. and 6½ ft. long, has a capacity of 110 gal. and normally operates at 60 lbs./sq.in. gage and 250° F. This tank is connected to both the hot and cold systems and serves to equalize the Dowtherm inventory between the two systems. The storage and expansion tanks are equipped with steam coils to prevent solidification of the Dowtherm at low ambient temperatures.

Temperature control at the users is maintained by an automatic controller in conjunction with normally closed solenoid valves located in the hot Dowtherm inlet. The control instrument employs a rotating cam to interrupt the flow of current to the solenoid valve for an interval dependent upon the departure of the temperature from the control point. The cam permits a one-second minimum impulse on a one-minute cycle, so that the solenoid valve can be in the open position for any interval from 1 to 60 sec./min.

Instrumentation for the heater is shown in Figure 2. The temperature of the Dowtherm leaving the heater is controlled by an automatic temperature-indicating controller (A) actuating an automatic gas valve (B). The heater is equipped with a multiplicity of safety devices. Should the pilot flame be extinguished, a thermocouple-actuated instrument (C) automatically closes a solenoid valve (D) in the pilot gas line and a quick-closing valve (E) in the main gas line to the burners. The pilot can be relighted only from a push-button switch (F), which opens the solenoid valve and actuates a spark-generating device (G) to ignite the pilot. The quick-closing valve must be manually opened and will remain open only when the pilot is burning. Cut-offs (H) and (I) actuate the quick-closing valve should the temperature of the Dowtherm exceed an established limit or should the

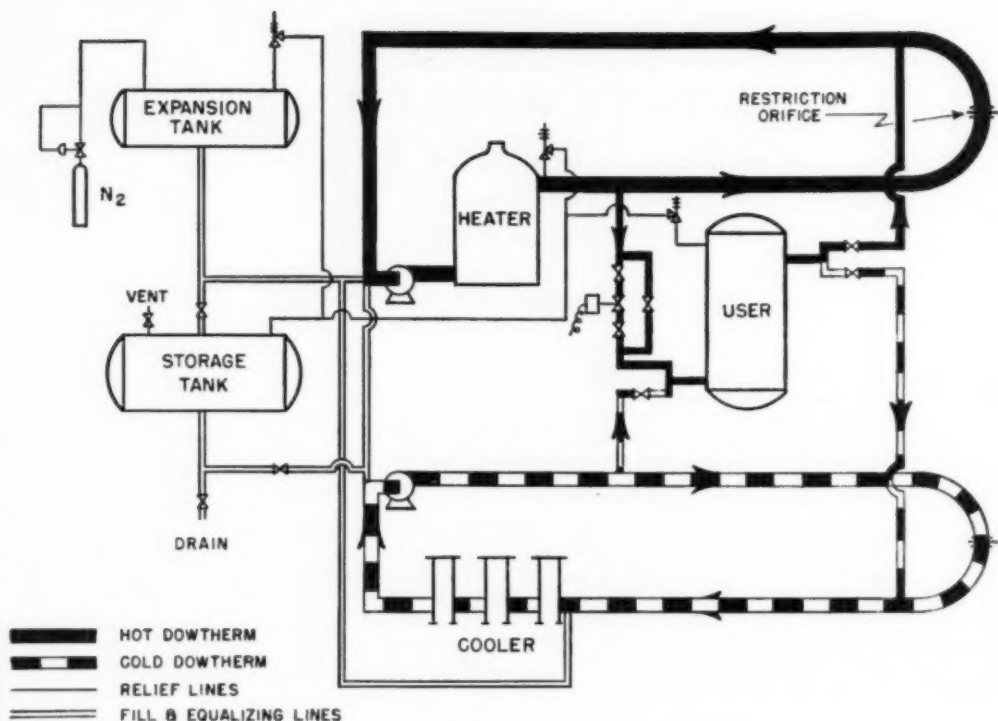


Fig. 1. Dowtherm system.

liquid level in the heater drop below a predetermined minimum. An electrical failure will also shut the quick-closing valve and the solenoid valve in the pilot-light gas line. When the quick-closing valve is shut by any of the safety devices, a horn indicates this fact to personnel.

### Installation and Start-Up

As a safety consideration, the major items of equipment for both the hot and cold systems are housed in a small annex outside the laboratory. The interior of this annex is shown in Figure 3. The heater is surrounded by a low concrete wall which would serve to retain Dowtherm accidentally escaping from the vessel. The safety devices and temperature controls are adjacent to the heater, with the pilot-light push-button

switch just inside the door of the annex. The storage tank is at a low point in the system to permit gravity return of the bulk of the Dowtherm if it should be necessary to drain the unit.

All piping is of welded construction, with ring-type flanged joints only where necessary to facilitate removal of lines for maintenance. Water in the system might cause hydrolysis of Dowtherm at elevated temperatures and might also vaporize with explosive violence if it should enter the fired heater. Consequently careful attention was given to the elimination of water by air-blowing the lines prior to installation. Vent valves are located at high points in the piping to facilitate removal of any air and water that accumulate when the system is in operation.

As Dowtherm will escape through the most minute openings, a stringent testing

procedure was carried out. To locate and repair leaks before the system was charged with Dowtherm, the piping was subjected to an air test at 100 lb./sq.in. gage. The system was then filled with Dowtherm and pressured hydrostatically to approximately 600 lbs./sq.in. gage. Leaks found during the latter test were repaired after the faulty sections of line were drained, removed, and purged with steam.

When the testing procedure was completed, the system was again filled by hand-pumping Dowtherm into the storage tank and thence through the system by means of the hot and cold pumps. Dowtherm at room temperature was circulated through the system for several days to flush the piping and to check the operation of the pumps; lines were vented frequently and temporary strainers, which had been installed upstream of all major items of equipment, were re-

TABLE 1.—PARTIAL EQUIPMENT SPECIFICATIONS

Item	Hot Pump	Cold Pump		Cooler	Heater
	Centrifugal	Centrifugal		Fin-Tube	Shell & Tube Liquid Phase
Material Circulating	Hot Dowtherm	Cold Dowtherm		Dowtherm Water	Dowtherm Hot Gas
Design Temperature, °F. ....	800	650	Shell: Tube:	750 450	800 ...
Design Pressure, lbs./sq.in. gage ....	175	175	Shell: Tube:	500 500	100 ...
Heat-Transfer Area, sq.ft. ....	...	...		78	72
Design Capacity: gal./min. ....	30	30		...	...
M B.T.U./hr. ....	...	...		100	300

moved occasionally and cleaned. The expansion tank was then pressured with nitrogen to approximately 60 lbs./sq.in. gage to maintain Dowtherm in the liquid phase at operating temperatures. The heater was fired and the Dowtherm temperature was increased slowly. When predetermined temperatures were reached, materials were charged to the users and temperature-control instruments were checked.

### Operation of Unit

Under normal operating conditions, the automatic control on the heater is set to provide Dowtherm slightly above the temperature desired at the hottest user. The automatic instrument controlling the particular user is then adjusted for the desired temperature and the by-pass around the solenoid control valve is opened. When the predetermined operating temperature of the user is approached, the needle valve upstream of the solenoid valve is opened and the by-pass valve is closed. If too much hot Dowtherm is being supplied through the solenoid valve at the minimum open time of one second, the needle-valve setting is correspondingly reduced; such adjustments are necessary when the temperature of the entering Dowtherm is considerably above the desired user temperature. Users operating at temperatures considerably below that of the hot stream are controlled by blending hot and cold Dowtherm at the user. The cold Dowtherm is added at a constant rate, and the automatic instrument in the hot stream varies the input to maintain the user at the predetermined temperature. The Dowtherm from the user may be discharged into either the hot or cold return line, the choice depending upon the temperature of the exit Dowtherm and the heat loads on the systems.

The liquid-phase Dowtherm unit described has been in service for three years. Endothermic reaction temperatures ranging from 200° to 550° F. have been automatically controlled within 3° F. maximum deviation. Although the unit was also designed to control exothermic reactions, such operations have not yet been carried out; however, experience gained thus far has indicated that the equipment is capable of controlling exothermic reactions. A larger unit has been designed for use with other pilot-scale equipment. This unit will furnish Dowtherm at temperatures ranging from 325° to 650° F. with an output of 1,000,000 B.t.u./hr., and will provide for removal of 500,000 B.t.u./hr.

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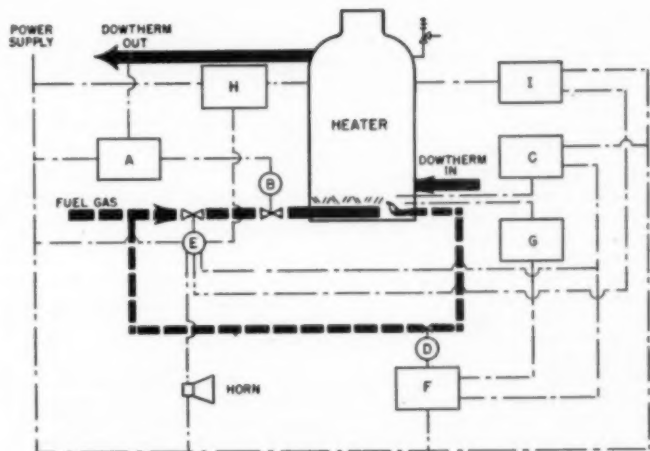


Fig. 2. Instrumentation for Dowtherm heater.

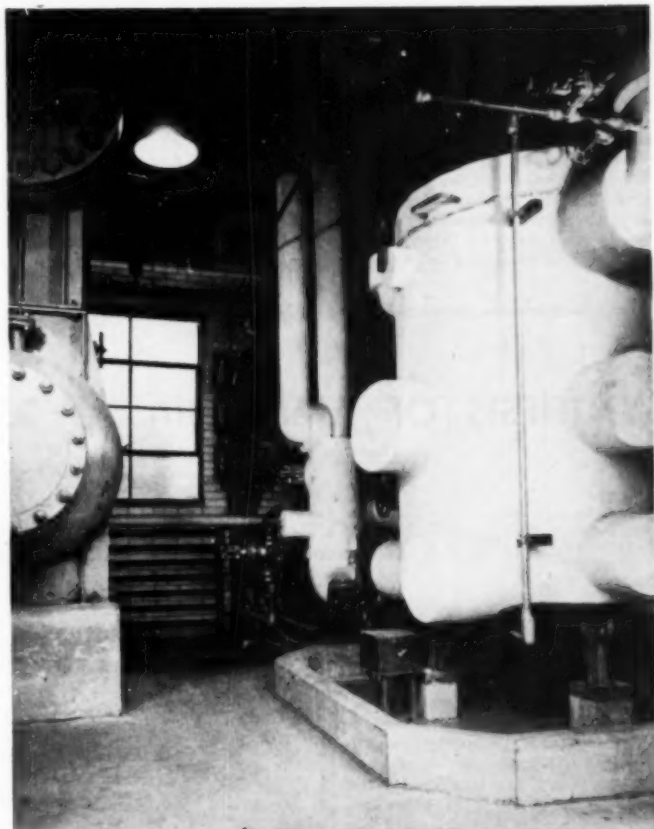


Fig. 3. Liquid-Dowtherm unit.

Expansion and storage tanks at left, heater at right, cooler against rear wall, and pumps at lower center.



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### Discussion

**H. C. McKee** (Jefferson Chemical Co., Austin, Tex.): Do you have any experience which would indicate how the system might operate with an intermittent or varying heat demand such as heating a reactor to initiate an exothermic reaction and then cooling to remove the heat evolved?

**J. E. Friden:** That is the type of operation that we anticipated in the original design. The heating system would be employed to initiate the reaction. When the reaction has started and heat is being liberated, the cooling system would come into play to control the temperature.

One might conceivably be interested in obtaining some idea of the liquid-Dowtherm coefficients compared with those of Dowtherm vapor or of other forms of heating. The accompanying figures are based on the heating of varnishes in kettles. (See Table A.)

In the instances cited, the liquid and vapor coefficients are about the same. Under conditions involving materials such as greases, which we were processing, or varnishes, the controlling resistance is usually the grease or varnish film. In other cases, the Dowtherm film itself might be controlling, with consid-

TABLE A.\*

Heat- ing Medium	Equip- ment	Heat- ing Sur- face	Over-all Coeff. B.t.u./ (hr.) (sq.ft.) (°F.)
Hot gas	Kettle	Copper	1-3
Dowtherm vapor	Jacketed kettle	Steel	20-50
Dowtherm liquid	Jacketed kettle	Steel	15-40

\*Dow Chemical Co., "Dowtherm—The Heat Transfer Medium for High Temperatures."

erable difference between liquid and vapor coefficients. I have no data at hand on coefficients for heating and cooling Dowtherm itself.

**J. E. Pierce** (Dow Chemical Co., Midland, Mich.): How well are you satisfied with your horizontal centrifugal pumps as far as leakage of the stuffing box? We have found that we like to use sump-type pumps where the stuffing boxes are out of the liquid.

**J. E. Friden:** In the initial installation we employed a mechanical seal in the packing gland. This was not satisfactory, either because of faulty installation or because the seal could not withstand the rigorous service.

In the present installation, we have a stuffing box which is sealed with a ring of laminated aluminum, several rings of metallic face packing, a lantern ring, and several more rings of metallic face packing. We pipe a small amount of Dowtherm from the discharge of the cold pump and supply it to the lantern ring, to flush and cool the packing gland

in the hot pump. This arrangement has given satisfactory service.

**Anonymous:** We have a similar system using Monsanto's Aroclor No. 1248. I wonder if you have done any work with Aroclor and what advantages there are compared with Dowtherm?

**J. E. Friden:** We have not evaluated Aroclor No. 1248 as a heat-transfer material.

**E. W. Neben** (The Pfaunder Co., Rochester, N. Y.): I think I can add something about different heat-transfer mediums. Materials like Aroclor 1248 or heat-transfer oils don't have to be pressured like Dowtherm in order to keep them liquid. This permits less costly equipment design and minimizes the possibility of leakage.

Dowtherm is more hazardous and harder to hold in a closed system. More safety devices are necessary with it.

Heat-transfer coefficients are comparable on an over-all basis as the material in the reactor usually governs this.

Dowtherm costs less per pound than the Aroclor 1248 and heat-transfer oils. There is also the possibility of dissociation of the Aroclor when high temperatures are reached. These might be considered as disadvantages.

In any event, before using any of the Aroclors or heat-transfer oils, their characteristics should be investigated with their manufacturers for the particular application.

(Presented at A.I.Ch.E. Meeting, Atlanta, Ga.).

## SYNTHESIS OF AMMONIA AT 350 ATMOSPHERES

L. B. HEIN

Tennessee Valley Authority, Wilson Dam, Alabama

**P**ROCESSES for the production of ammonia may be classified as low- or high-pressure processes according to the pressures to which the hydrogen-nitrogen mixture is subjected during synthesis. About 70 per cent of the synthetic ammonia in this country, and in the world, is produced by low-pressure processes, which are considered to be those operated at 130 to 350 atm. This paper describes the general flow system in the synthesis section of low-pressure processes and several converters that are typical of those used in these processes.



Lawrence Hein, now chief of the defense processes section of the Tennessee Valley Authority's Division of Chemical Development at Wilson Dam, Ala., joined TVA in 1947 as a project leader. His work has been in connection with process studies on ammonia and nitric acid and pilot-plant development of new processes. Prior to his association with TVA he was on the chemical engineering staffs at Michigan State College and the University of Arkansas. He received his B.S. (1937) and M.S. degrees from Oklahoma A. and M. College and his Ph.D. from Michigan State College.

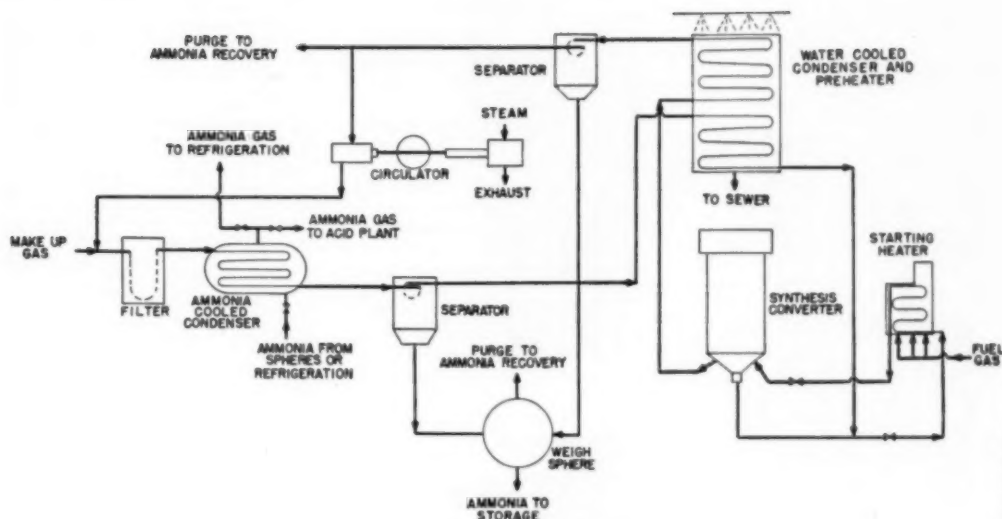


Fig. 1. Flow diagram for the ammonia synthesis section of TVA plant.

**Preparation of Synthesis Gas.** Most of the synthetic ammonia plants in this country obtain their hydrogen through reaction of natural gas with steam in the presence of a nickel catalyst or through reaction of coke with steam in water-gas sets; reformed gas and water gas, respectively, are produced. The nitrogen requirement usually is supplied through addition of air or of flue gas to the reformed gas or through addition of nitrogen-rich gas from the blow run of the water-gas sets.

Methods used for purifying the hydrogen-rich gas in plants that use coke or natural gas are quite similar. Carbon monoxide in the gas is oxidized to carbon dioxide by the well-known water-gas shift reaction; the gas then is brought to synthesis pressure in multi-stage compressors. The bulk of the carbon dioxide in the gas is removed at a pressure of from 15 to 20 atm. by scrubbing with water or by scrubbing with monoethanolamine solution (Girbotol process). Residual carbon monoxide, carbon dioxide, and oxygen are removed by scrubbing with a copper-ammonium formate solution at about 120 atm. If the carbon dioxide content of the gas has not been lowered to tolerable limits in the copper solution scrubber, the gas ordinarily is scrubbed with caustic solution.

Purification and compression of the gas are carried out simultaneously, purification being an interstage operation.

Plants using by-product gas from

electrolytic cells or coke ovens have purification systems differing from those just described because of the difference in contamination.

The discharge pressure from the final stage of compression is governed by the process used and by the operating conditions in the synthesis section.

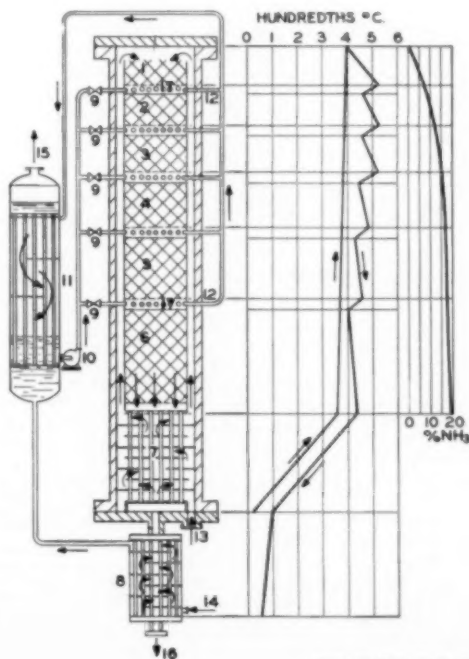


Fig. 2. Ammonia synthesis converter used in Fauver - Montecatini process.

Courtesy Montecatini Co.

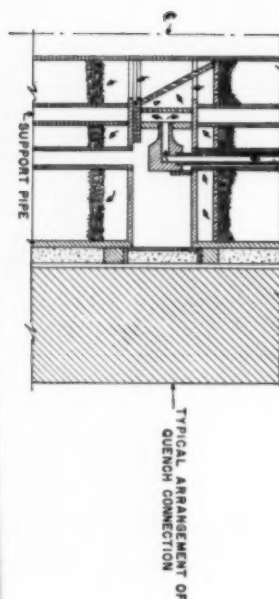
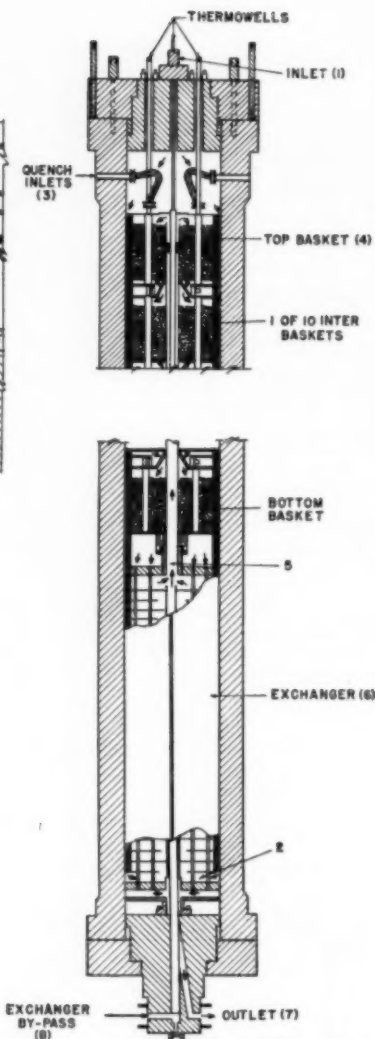
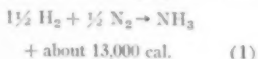


Fig. 3. Ammonia synthesis converter used in Kellogg process.



Courtesy Commercial Solvents Corp.

**Synthesis.** Synthesis of ammonia from hydrogen and nitrogen occurs according to the following equation:



To obtain an acceptable reaction rate, the synthesis is carried out under pressure, at elevated temperatures, and in the presence of a catalyst. Even then the yield of ammonia is so low that recycling of unreacted gas is practiced. Because of economic reasons, ammonia is not removed completely from the synthesis gas.

A flow diagram of the synthesis section of the Tennessee Valley Authority ammonia plant, which is typical of low-pressure processes, is given in Figure 1.

Fresh synthesis gas, together with recycle synthesis gas, is passed through a filter where oil and other liquid or solid particles are removed.

From the filter, the gas flows to an ammonia-cooled condenser where the ammonia content of synthesis gas is decreased to about 4 per cent. The amount of  $\text{NH}_3$  removed varies widely because the ammonia content of the gas to the condenser is dependent on the effectiveness of the water-cooled condenser that is employed for the

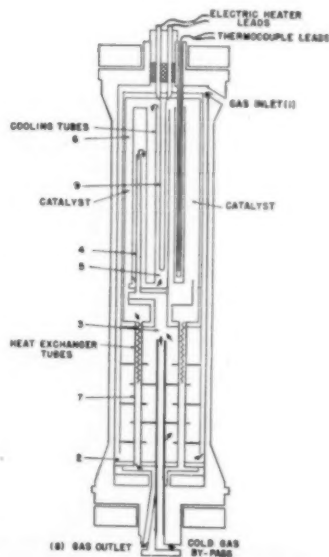
removal of ammonia from the gases as they leave the converter.

A second function of this condenser is to remove impurities such as carbon dioxide and moisture, which are harmful to the synthesis catalyst. The addition of make-up gas ahead of the condenser in the synthesis circuit increases the size of condenser required; however, refrigeration of make-up gas has been found to be an effective means of purification.

From the ammonia-cooled condenser, the gas is passed through a separator, a heat exchanger, and then into the synthesis converter. Warm water from the water-cooled condenser is used in the heat exchanger.

The ammonia converter is a combination of heat exchanger and catalyst basket. Here the synthesis gas is heated further and reaction between hydrogen and nitrogen occurs. Incoming gas is heated through exchange with outgoing gas and the heat of reaction in the catalyst is sufficient to maintain catalyst temperature. Although the ammonia content of the gas at equilibrium is increased by high pressure and low temperature (2), a catalyst temperature of about 500° C. is used to obtain a satisfactory rate of reaction. When the catalyst loses activity, it is necessary to increase the temperature gradually. Most converters operate at a space velocity of 10,000 to 20,000 cu.ft. (S.T.P.) of effluent gas/(hr.) (cu.ft. of catalyst). Within limits, increasing the space velocity results in increased production; however, excessive space velocity disturbs the thermal balance in the converter and increases the difficulty of ammonia recovery because of the lower concentration of ammonia in the gas.

Methane and argon in the raw gas produced from natural gas or coke are not removed in the purification system and therefore accumulate in the recycling gas.



Courtesy Chemical Construction Corp.

Fig. 4. Ammonia synthesis converter used in Nitrogen Engineering Corp. process.

Although methane and argon do not seriously deactivate the catalyst, their presence decreases the rate of the synthesis reaction by decreasing the partial pressure of hydrogen and nitrogen and by dilution of reactants (7). Inerts are removed from the closed synthesis circuit by purging and by dissolving in the product ammonia.

Deviation from a 3:1 hydrogen-nitrogen ratio in the gas to the converter also decreases ammonia production capacity.

From the converter, the gas is passed through a water-cooled condenser and then through a separator for the removal of a portion of the ammonia. The proportion of ammonia removed varies with the temperature of the water and the condition of operation of the converter; during normal operation from one half to two thirds of the ammonia in the gas is removed at this point; as stated previously, additional ammonia is removed after condensation in the ammonia-cooled condenser.

From the ammonia separators the synthesis gas is compressed in a circulator to restore the pressure lost because of friction and decrease in gas volume and then is combined with fresh make-up gas in the filter.

Ammonia in the purged gas is removed by refrigeration and by scrubbing with water, and the remainder of the gas is vented to the atmosphere. Ammonia is stripped from the water solution. Dissolved gases in the liquid ammonia are released when the pressure on the ammonia is reduced before the ammonia is placed in storage. Ammonia that escapes with these gases is recovered in the same equipment as that used for the recovery of ammonia from the purged gas.

**Synthesis Converter.** The synthesis converter is the heart of the plant. To provide for proper operation of this relatively small piece of equipment, much equipment is needed for gas production, purification, and compression.

The most important factors in the design of a converter are the arrangement of heat exchangers so that gas is made to flow through the converter in such a way as to maintain an optimum catalyst temperature, design such that no sudden changes in temperature occur anywhere, and the use of construction materials capable of withstanding pressures, high temperature, and chemical attack.

Temperature control is extremely important because the attainment of a reaction rate high enough to make the process economically feasible requires operation at a temperature near that at which catalyst deactivation becomes rapid and materials are attacked at an appreciable rate. Heat released from the synthesis reaction is not uniform throughout the catalyst bed and hence there is a tendency toward localized overheating. Furthermore, the "hot spot" is shifted through changes in the conditions of operation and through aging of the catalyst. Therefore, in the ideal converter, it is desirable to control the removal of heat at each point in the converter. Such a converter has not been developed but there are converters that

approach this ideal arrangement. In other converters the heat exchangers and the flow of gas are arranged to minimize the temperature difference in the catalyst that is caused by the heat of reaction.

Alloyed tubes are used in the heat exchangers of modern converters. The arrangement is such that the exchanger tubes, which operate at high temperatures, are not required to withstand pressure differentials and the converter shell, which has synthesis pressure on one side and atmospheric pressure on the other, is kept at a low temperature to prevent weakening of metal.

Shell temperatures are kept low by the flow of cool gases next to and inside the shell and through use of an insulating material between the cool gases and the internals of the converter.

Ammonia synthesis converters may be considered to be of two types. One type employs layers of catalyst with means for cooling the gases between layers. This type, in which the temperature of the gas is controlled at various levels in the converter, is an approach to point-by-point temperature control and is exemplified by the Fauser-Montecatini converter as shown in Figure 2 and by the converter designed by the M. W. Kellogg Co. as shown in Figure 3. The Nitrogen Engineering Corp., Tennessee Valley Authority, and Mont Cenis processes employ converters in which gas flow and heat exchangers are arranged to minimize temperature difference in the catalyst. The NEC converter is shown in Figure 4. The TVA-type converter as designed by C. O. Brown for the TVA is shown in Figure 5.

**Fauser-Montecatini Converter.** The most recent modification of the Fauser-Montecatini converter (Fig. 2) is unique in that steam is produced from surplus heat generated by the synthesis reaction. Synthesis gas enters the converter at (13), passes through the shell side of heat exchanger (7), flows upward in the annular space between the converter shell and catalyst basket, downward over the layers of catalyst (1-6), and through the exchanger tubes (7) to the converter outlet. The temperature of the gas during its upward and downward flow and its ammonia content also are given in the figure. Feed water enters an economizer (8), which may or may not be used, passes to flash chamber (11), through a circulation pump (10), through the converter shell to coils (17) in the converter, and through the converter shell (12) back to the flash chamber. Valves (9) are used to control the rate of water flow through the coils at various levels and thereby control the temperature in the converter.

The following data are said to apply to the Fauser-Montecatini converter:

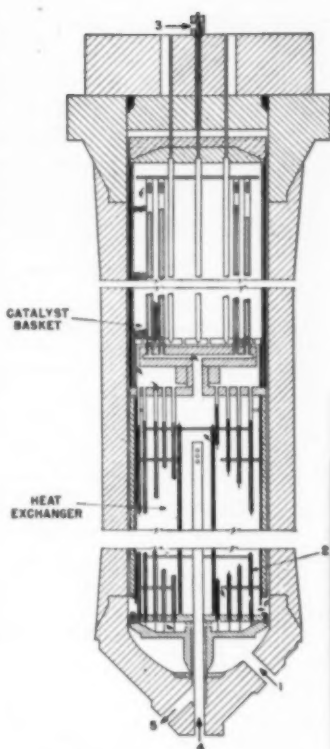


Fig. 5. Ammonia synthesis converter used in TVA process.

Working pressure, atm. ....	300
Ammonia production, tons NH <sub>3</sub> /day ..	55
Ammonia content of gas, % .....	1.5
Inlet to converter .....	20.0
Outlet from converter .....	20.0
Temperature of gas, °C. ....	30
Inlet to converter .....	30
Outlet from converter .....	100
Steam production, 150 lb./sq.in. gage,	
250° C. ....	0.8
lb. steam .....	
lb. NH <sub>3</sub> produced .....	

Advantages claimed for the converter are (1) increased thermal efficiency to produce steam from surplus heat and (2) improved control of catalyst temperature to increase ammonia production capacity and decrease power consumption for gas circulation.

Montecatini has recently installed this type converter at its Merano and Novara works in Italy. (Information on the converter was supplied by the Montecatini Co., Milano, Italy.)

**Kellogg Converter.** In the Kellogg converter (Fig. 3) gas enters the converter at (1), passes down the annular space between the shell and internals of the converter to the bottom of the heat exchanger

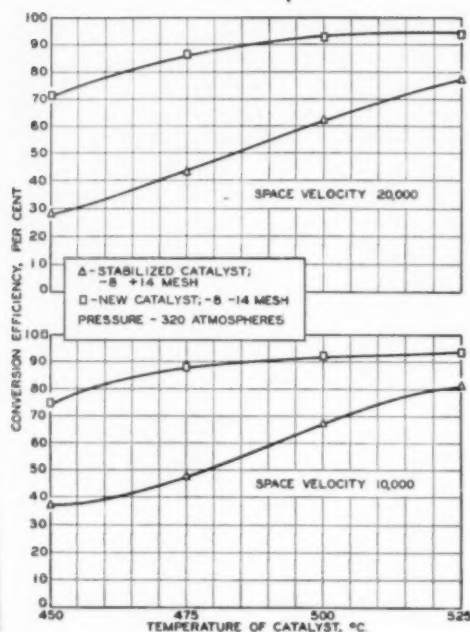


Fig. 6. Comparison of conversion efficiency of new and used ammonia synthesis catalysts.

(2), upward through the shell side of the heat exchanger (6), through center pipe of the catalyst basket (5), downward over the layers of catalyst (4), and through the heat-exchanger tubes to outlet (7). Gases for control of temperature by quenching between catalyst layers enter at (3). The degree of preheat of the gas to the top of the catalyst is controlled by the by-passing of a portion of the inlet gas around the heat exchanger. The inlet for the by-pass gas is at the bottom of the converter at (8).

The converter operates at about 350 atm., and 80 cu.ft. of catalyst is employed. The converter is operated to produce 100 tons of ammonia/day. Catalyst life experienced in this converter has been about four years.

(Information on the converter was supplied by Commercial Solvents Corp.)

**NEC Converter.** The NEC converter (Fig. 4) is an example of the type in which temperature differences in the catalyst are minimized by the arrangement of heat exchangers and gas flow. This converter is designed by the Chemical Construction Corp.

The converter consists of a heat exchanger in the lower section and a catalyst basket with cooling tubes in the upper section. The main gas flow enters near the top of the converter at (1), flows downward through the annular space next to the outside shell and enters the bottom of the heat-exchanger section (2) outside the tubes. Near the top of the heat exchanger (3) the gas is mixed with cold by-pass gas in such proportion as to give the desired operating temperature in the catalyst.

The cooling tubes (4) in the catalyst basket are of double pipe sections. Gas flows upward through the inner pipes, downward through the annular spaces to a

header, upward again through a collecting tube (5), downward through the catalyst outside the tubes (6), and then through the heat-exchanger tubes (7) to the converter outlet (8). Heat exchange to control catalyst temperature is between gases inside and outside the cooling tubes in cocurrent flow.

The converter is fabricated in two sizes of 700 and 800 mm. diam. The smaller one contains 53 cu.ft. of catalyst and the larger one contains 70 cu.ft. At 350 atm., these converters will produce from 1.5 to 1.9 tons of ammonia/(cu.ft. of catalyst)(day) depending on the concentration of inerts in the recycle gas, temperature of cooling water, and amount of refrigeration employed in the process.

An electric heater (9), located in the gas-collecting tube (5), is provided for heating the gas used to preheat the converter. The heater also may be used to control the temperature of the gas entering the catalyst. It is claimed that the heater usually has a life equal to that of the inside metal parts of the converter. (Information on the converter was supplied by the Chemical Construction Corp.)

**TVA Converter.** This converter also is designed for gas flow and heat exchange to minimize temperature differences in the catalyst (Fig. 5). The main flow of synthesis gas enters the bottom of the converter at (1) and is preheated by counter-current heat exchange (2) with hot gas flowing downward from the catalyst. Gas leaves the converter at the bottom (5). Synthesis gas for cooling the outside shell of the converter enters the top (3), passes down the converter through the annular space next to the shell, and mixes with the main gas flow at the base of the exchanger. Gas that is by-passed around the exchanger to control catalyst temperature enters the bottom of the converter at (4) and mixes with the remainder of the synthesis gas in the upper part of the heat exchanger.

The converter, which contains 144 cu.ft. of catalyst, is operated at a pressure of from 250 to 350 atm. The amount of catalyst in this converter exceeds the presently installed capacity for compressing synthesis gas. Ammonia production from this converter is about 140 tons/day.

Aside from structural differences between this converter and the NEC converter, heat transfer in the TVA catalyst basket is accomplished through countercurrent flow of gas whereas in the NEC catalyst basket the flow is cocurrent. Considerable controversy has existed among designers as to whether countercurrent or cocurrent gas flow in the converter is more effective in maintaining optimum temperatures throughout the catalyst. Calculations indicate that at normal operating conditions the mean-temperature difference between gas inside the tubes and that passing through the catalyst is about the same for either type of flow. Satisfactory control of catalyst temperature by either method is indicated by the fact that both types of converters have given efficient operation for prolonged periods.

A gas-fired heater located outside the converter is used for heating the synthesis gas with which the TVA converter is brought to operating temperature. Because of the time required to place the heater in operation, heat from this source cannot be supplied quickly to supplement heat of reaction as is desirable occasionally.

**Mont Ceniz Converter.** The converter used in the Mont Ceniz process, which operates at about 160 atm., also is designed to minimize temperature differences in the catalyst. Preheated gas from heat exchangers located outside the synthesis converter

TABLE 1.—SPECIFICATIONS FOR TUBING AND AUXILIARIES USED IN TVA SYNTHESIS PLANT

Part	Specifications
Tubing for cold gas	{ SAE 4130X, with tolerances per ASTM A290-40
6-in. O.D. by 4 in. I.D.	ASTM-A192-40
5½-in. O.D. by 2½ in. I.D.	ASTM-A192-40
4-in. O.D. by 2 in. I.D.	SAE 6120
Tubing for hot gas	A192-39 Class F1
Flanges	{ SAE 4140 with physical properties per ASTM-A96 Class C
Studs and nuts	ASTM-A194 Class 2H
Studs	
Nuts	



enters the converter at the bottom and travels upward in the space between the shell of the converter and catalyst basket. The gas is heated further by passing through tubes in the catalyst bed. The gas flows downward through the inner of two concentric tubes, then upward through the annular space between the tubes, and out to the top of the catalyst bed. The tubes extend downward the length of the catalyst bed. From the tubes the gas flows downward through the catalyst and leaves through the bottom of the converter.

The converter is charged with 16 tons of catalyst and is capable of producing 200 tons of ammonia/day when operated at 20,000 space velocity. The life of the catalyst in this converter is reported to be about four years.

(Information on the converter was supplied by the Shell Chemical Corp.)

**Catalyst.** The most widely used catalyst for ammonia synthesis is one of iron promoted with aluminum and potassium oxides. As prepared in the oxidized state, the catalyst contains 1 to 3% aluminum oxide and about 1% potassium oxide. It is preferable that ferrous and ferric iron be present in a ratio of 1 to 1. The iron in the catalyst is reduced to the metallic state in the converter with hot synthesis gas. Details for the manufacture of this type of catalyst have been published by Bridger et al. (7).

It is desirable that a catalyst for synthesis of ammonia have a long, useful life because, aside from the cost of the catalyst and the time required to replace it, the procedure for shutting-down and starting up a synthesis train is intricate and time-consuming. Labor plus loss of production during a shutdown makes replacement of catalyst expensive. For this reason care is taken during the manufacture of a catalyst to prevent its contamination. After reduction, the catalyst is extremely sensitive to poisoning by oxygen, carbon oxides, sulfur, phosphorus, chlorine, and other substances (1). During normal plant operation, the oxygen content of the gas usually is nil and the carbon oxides content is kept below 10 p.p.m. A carbon oxide content in the gas of only 50 p.p.m. ordinarily is not tolerated for more than 15 min.

After seven and one-half years of service the catalyst in the TVA plant was removed because of the high pressure and temperature required in the synthesis converter to maintain production. After the catalyst was removed from the converter, the apparent decrease in activity was investigated by testing the catalyst in a small converter in the laboratory. The laboratory tests showed that, with the small converter operated at plant conditions of 320 atm., 500° C., and space velocity of 10,000, the conversion efficiency of the used catalyst was only 67%, whereas that of the new catalyst under identical condi-

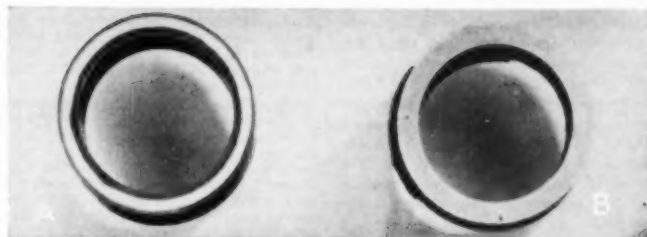


Fig. 7. Nitriding of heat-exchanger tubes.

Courtesy A. O. Smith Corp.

TABLE 2.—DEPTH OF NITRIDING OF THE SECTIONS OF TUBES SHOWN IN FIGURE 8

	Inch	
	Outside	Inside
A Inner cooling tube (top) .....	0.02	0.015
B Inner cooling tube (middle) .....	0.04	0.04
C Inner cooling tube (bottom) .....	0.02	0.02
D Outer cooling tube (top) .....	0.01	0.01
E Outer cooling tube (middle) .....	Nitrided throughout	
F Outer cooling tube (bottom) .....	0.04	0.02

tions was 92%. Channeling in the plant converter, as indicated by temperature measurements in the catalyst, probably decreased the effectiveness of the cata-

lyst below that indicated by the laboratory tests. Conversion efficiencies of the new and used catalyst at other temperatures and at space velocities of

TABLE 3.—ENERGY REQUIREMENTS FOR AMMONIA PRODUCTION

Section of plant	Requirements per ton of ammonia					
	From process using coke			From process using natural gas		
	Coke, tons	Net steam used, M lb.	Electricity, M kw.-hr.	Natural gas, <sup>1</sup> MCF	Net steam used, M lb.	Electricity, M kw.-hr.
Gas production .....	1.4	0.3	0.03	33.5	0.6	0.040
CO conversion .....	...	7.8 <sup>2</sup>	0.02	...	1.5 <sup>2</sup>	...
Gas compression—purification .....	...	1.84 <sup>3</sup>	1.0 <sup>3</sup>	...	1.84 <sup>3</sup>	1.00
Refrigeration .....	...	0.53 <sup>4</sup>	...	...	0.53 <sup>4</sup>	...
Ammonia synthesis .....	...	0.37 <sup>4</sup>	...	...	0.37 <sup>4</sup>	...
Total .....	1.4	10.84	3.14	33.5	4.84	2.04

<sup>1</sup> Natural gas assumed to have a high heating value of 1000 B.t.u./cu ft. (60° F., 30 in. Hg).

<sup>2</sup> Based on steam: CO ratio of 7:1. The bulk of this steam is exhaust from steam driven, industrial plant practice may change these values considerably.

<sup>3</sup> 85 per cent of consumption is exhaust steam used for heating copper liquor.

<sup>4</sup> Values include only that steam condensed in drives.

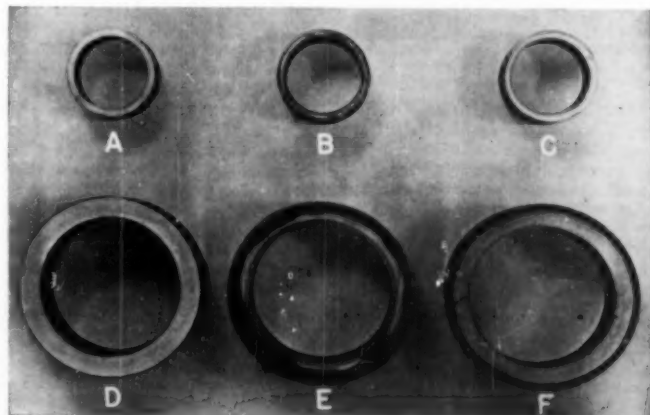


Fig. 8. Nitriding of catalyst-cooling tubes.

Courtesy A. O. Smith Corp.

10,000 and 20,000 are shown in Figure 6.

Chemical analyses showed that the sulfur content had increased from 0.005% in the unused catalyst to 0.028% in the used catalyst and that the phosphorus content had increased from 0.005% to 0.016%. Sulfur probably originated from coke, which was the source of the gas, or from oil used in the lubrication of the compressors; phosphorus probably originated from a phosphate plant nearby. Accumulation of sulfur and phosphorus probably contributed to the decrease in ammonia-producing capacity of the catalyst in the plant converters. Decrepitation of the catalyst probably was a contributing factor also. Screen analysis showed that only 38% of the used catalyst was plus 6 mesh in size; the size of the new catalyst when charged to the converter was minus 3 plus 6 mesh. It is recognized that a considerable proportion of the decrease in size probably occurred during removal of the used catalyst from the converter.

A catalyst during service is extremely pyrophoric and must be oxidized (stabilized) before being taken from the converter. Because of the large amount of heat released during stabilization, the converter may be damaged if this step is not carried out properly. The following procedure has been used successfully in the TVA plant:

The temperature of the catalyst was reduced to 20° to 30° C. by recirculation of synthesis gas. Synthesis gas was bled from the system until the pressure was reduced to atmospheric and then was replaced with nitrogen until the hydrogen in the system was reduced to 0.9%. Air was added in an amount such that the resultant gas contained 0.1 to 0.2% oxygen and the gas was circulated at a space velocity of 24 and a pressure of 4 atm. The catalyst was stabilized in 24 hr. during which the maximum temperature of the catalyst was maintained below 100° C. and the maximum temperature rise per minute was held below 0.26° C. through control of the oxygen content of the gas. After the stabilization treatment, the catalyst was removed from the converter and exhibited no evidence of excessive heating.

**Materials of Construction.** Gases in the TVA ammonia synthesis plant are transported through a number of different types of steel tubing. Specifications for tubing, flanges, studs, and nuts are shown in Table 1.

Materials within the synthesis converter are subjected to high temperature and pressure but the stresses due to pressure are small since the material is surrounded by gas at high pressure. Thermal stresses are minimized by careful design. The material is subject to hydrogen attack, however, and at points of localized temperature increase, it is subject to attack from nascent nitrogen formed through the cracking of ammonia, which may cause shrinkage, cracks, and fissures. In general, the metal used must be low in carbon, contain chromium to withstand hydrogen attack, and contain elements

to give satisfactory high-temperature properties. Some data may be found in the literature (3-6) on the effect of hydrogen and nitrogen on various metals at high temperatures and pressures.

Figure 7 is an illustration of the extent of nitriding of heat-exchanger tubes in the TVA converter that occurred during seven and one-half years of service. The tubes were fabricated of A.I.S.I. Type 501 steel. Figure 7A shows the extent of nitriding in the hot end of one of the tubes. The steel was so embrittled that a slight tap with a hammer caused it to shatter. The outside of the tube of 0.083-in. wall thickness was nitrided to a depth of 0.015 in. and the inside was nitrided to a depth of 0.03 in. Figure 7B, taken from that part of a tube subjected to lower temperature, did not show nitriding. Figure 8 shows the extent of nitriding of the catalyst-cooling tubes: A, B, and C are from the upper, middle, and lower sections of an inside cooling tube and D, E, and F are from the outer tubes at the corresponding points. Both inner and outer tubes were fabricated of A.I.S.I. Type 501 steel. Figure 8E is an illustration of the most severe nitriding in which the tube became embrittled almost throughout the wall, and numerous cracks are visible.

The depth of nitriding of the sections of tubes (Fig. 8) is shown in Table 2.

The wall thickness of the outer cooling tube was 0.266 in. and that of the inner tube was 0.093 in.

Heating the nitrided tube sections to 925° C. and then cooling the section in a laboratory furnace apparently diffused the nitrogen to the extent that the material was ductile. This is very likely the only heat treatment that could be used to improve ductility of the material under discussion since other heat treatments up to 650° C. were ineffective.

It has been stated that A.I.S.I. Type 501 steel has given satisfactory service for ten years at temperatures up to 500° C. Above 500° C., the rate of nitriding increases. At temperatures above 540° C., A.I.S.I. Type 304 stainless steel might give better service (3) than A.I.S.I. Type 501 steel in that the nitriding action is slow and embrittlement does not proceed below the case depth. (Much of the information regarding materials of construction was supplied by the A. O. Smith Corp.)

The outside shell of the converter vessel can be fabricated from steel of high tensile strength because its main requirement is to withstand the pressure of gases in the converter. A liner of chromium steel usually is placed inside the shell to protect it from chemical attack. In all modern converters the shell is insulated from the high temperature inside the converter by a flow of gas through an annular space between the shell and internal parts.

**Energy Requirements.** Energy requirements represented by the demands of coke or natural gas, steam, and electricity for the production of ammonia at 350 atm. are given in Table 3. Only the requirements for processes based upon the use of coke and natural gas as raw

materials are given because of the extensive use of these raw materials in the synthetic ammonia industry. Energy is given in the table because this is a basic requirement, whereas maintenance, labor, and other miscellaneous items are more dependent on the physical condition of the plant. Aside from the energy requirements, water (preferably cool) also is needed in large quantities. Values in the table are based upon the effective removal of the carbon dioxide by means of water scrubbing; consumption of electric power would be less and consumption of steam greater if monoethanolamine solution were used for this purpose.

Quantities in the table are based upon the use of steam drives for circulators for ammonia synthesis gas, refrigeration machines, copper liquor pumps, and semiwater gas blowers; large, multistage compressors for synthesis gas and all minor equipment are driven electrically. It is customary to employ some steam drives, particularly when synthesis gas is obtained from semiwater gas because of the high demand for exhaust steam for carbon monoxide conversion.

### Acknowledgment

The author wishes to express appreciation to the staff of the Office of Chemical Engineering of the Tennessee Valley Authority for its contributions to this paper.

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(Presented at A.I.Ch.E. Kansas City (Mo.) Meeting.)

### CORRECTION

In "Studies of Gas Bubble Formation," by D. W. van Krevelen and T. J. Hofstijzer, printed in the January, 1950, issue of "C.E.P." the following inaccuracies have been noted. In Figure 4, on page 33, which represents a general correlation for the critical flow rate of a bubbling gas, the unit in which  $V_a$  is expressed is cubic meters per second. Also on this graph lines 3 and 4 are reversed and the data of Bretnier and of Maier are transposed.

# THE CHEMICAL ENGINEER — A REGIONAL SURVEY

F. J. VAN ANTWERPEN

ON the next few pages, Chemical Engineering Progress publishes the results of a survey which, in the editor's opinion, is one of the most interesting yet run on chemical engineers. The survey was made by a joint committee of the New York and New Jersey Sections of the American Institute of Chemical Engineers, and information was asked only of members of the Institute living in those two states.

## Survey Philosophy

Behind the questionnaire was the desire of the committee to know more about what manner of men our fellow professionals were. Heretofore in surveys chemical engineers were nothing more, statistically speaking, than points on a survey curve. Little was known about the chemical engineer as an individual, still less was known about how he thought on social problems. There were many popular opinions as to his foibles, and the committee had an earnest desire to come as close to the truth about him as an individual as possible. Aside from studying his salary (and this is still of primary interest to the great majority of our readers), the committee wished to learn the truth of certain popular ideas about the chemical engineer which had been giving in recent years the appearance of becoming classical. We wished to know, for instance, whether or not he was sorry he had become an engineer, whether he wished his children to become engineers, was his education, difficult as it was, inadequate for the task industry was asking of him? Had his pragmatic approach, and his scientific background also, made him a nonbeliever? Had salaries failed to keep up with the times?

With these views in mind the committee set up an extensive questionnaire, and sent it to the members.

The task of comparing, and determining the results was divided among the committee members. As the questionnaires were returned, the pages were separated, a number being stamped on the back of each page, and sent to the committee members charged with the responsibility of correlating information in each particular field. Thus background

information went to C. W. Weil, Chas. Pfizer & Co., Inc., the page of the questionnaire dealing with education was sent to J. W. Hemphill, Johns Manville Sales Corp., the salary study, which had an enormous amount of statistical labor attached to it, was divided between W. T. Dorsheimer and Mason L. Downing. The information on hopes and ambitions was compiled by R. L. Demmerle, General Aniline & Film Corp.

By such a division the anonymity of each respondent was guaranteed. In case of doubt, or ambiguity, the numbering system on the back of each page allowed checking between the various sections in case it was needed. Thus when the committee members came across a comparatively young man claiming a salary far and beyond the typical experience for his age, they were able to determine whether, based on his worldly possessions and background, such a salary was likely.

The survey had its faults, and this is admitted by the committee. One was its limitation to the New York and New Jersey area, another is the fact that in the metropolitan area, salaries are higher than for the country as a whole.

At the time the survey was being made we had access to another salary curve,

compiled by the Engineers Joint Council. This survey is shown for comparison in some of the curves on salary, and in Figure 1 of this introduction. From this curve one can see that the assumption made above, that salaries in the New York and New Jersey area are higher than in the country as a whole, has validity.

Regarding the other phases of our results: we believe that this sample, representing the thousand-odd valid returns, will hold for the rest of the country. We believe that should a survey be made for the whole Institute membership covering education, background and hopes, there would be little change from the present conclusion.

As far as the physical facts of the questionnaire are concerned—it was five pages long, went to 2,220 members, and returns were received from 1,067 members, a return of 48%.

The committee feels that the results have warranted the effort, and that the statistical picture of the chemical engineer shows him to be among the elite salarywise, in his relations with his fellow man, and in his aspirations. As far as his background is concerned, he is as American as quahog chowder and barbecued spareribs.

The committee was as follows:

F. J. Van Antwerpen—Chairman  
R. L. Demmerle—Future  
W. T. Dorsheimer—Salary  
M. L. Downing—Salary  
J. W. Hemphill—Education  
C. W. Weil—Background

## Salary Comparison

The Editor must explain Figure 1 in this study. On May 6 he gave before the New Jersey Section of the A.I.Ch.E. a talk on salary comparisons. A request was made at that time that a chart showing how chemical engineers compared with doctors, lawyers, and dentists be published. For that reason, and also for the comments made in the salary survey by W. T. Dorsheimer on doctors' salaries, this is done here in Figure 1. By way of explaining the source of material, the data on the chemical engineers were obtained from the study soon to be made public by the U. S. Department of Labor, Bureau of Labor Statistics.

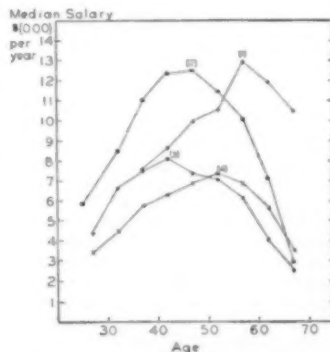


Fig. 1. Comparison of salaries of different professions.

- (1) Chemical engineers
- (2) Physicians
- (3) Dentists
- (4) Lawyers

It covers only the Active members of the A.I.Ch.E. and will be titled, "Employment, Education, and Income of Engineers, 1949-50." This work was done in cooperation with the Federal Security Agency, Office of Education, National Scientific Register, based on a survey made by the Engineers Joint Council on behalf of the Department of Defense. The information on doctors is based on a Department of Commerce study, pub-

lished in the Survey of Current Business, July, 1951. It must be mentioned, however, that the published figures cover average salary only, and the median salaries shown on the curve were obtained from the Department of Commerce. The information on dentists came from a study published in the January, 1950, Survey of Current Business, and the information on lawyers from the August, 1949, issue of the same magazine.

## HIS BACKGROUND

CARL W. WEIL

Chas. Pfizer & Company  
Brooklyn, New York

**P**ICTURE if you will our average chemical engineer. He's a man about 33 years old who stands 5 ft. 10 in. tall. This makes him taller by about 2 in. than the average inductee of World War II. Of his group 35% are 6 ft. tall or more. He weighs a hefty 171 lb. He likely has brown hair and blue eyes.

As to his nationality and origin, he is in a group 94% of whom were born in the U.S.A., with Canadians and Germans ranking next. Although generally his parents were born here, 30% of them came from foreign countries, with Russia, Germany, Poland, Italy, Austria, England, and Canada ranking in that order. This percentage of foreign born among his parents is more than double the average of 13.5% foreign born in the U. S. in 1920 (the time of his birth), and the preponderance of Russian parents is above that expected from the national population. The average number of persons in the family of his birth is 4.9 which is slightly above the average for the country as a whole. (See Table 1.)

What the engineer does in his free time is another matter of concern. Almost universally he spends a full eight-



**CARL W. WEIL** is a development supervisor in the research and development department of Chas. Pfizer & Co., Brooklyn, N. Y. He received his Ph.D. in chemical engineering at the University of Delaware in 1951. Previously he had attended Carnegie Institute of Technology for his Bachelor of Science and Master of Science work. He was employed by Carbide and Carbon Chemicals Co. prior to and following a four-year tour of duty with the U. S. Army.

TABLE 2.—HOBBIES  
Participation—96%  
Hobbies per Hobbyist—2.0

Sports .....	42%
Photography .....	27
Woodworking .....	18
Music .....	18
Gardening .....	17
Reading .....	17
Stamps .....	8
Home Repairs .....	7
Others .....	17

hour day a week on hobbies which average two for each hobbyist. As shown in Table 2, 42% of the engineers consider sports the No. 1 hobby. Later on in the questionnaire, however, 85% of the repliers listed at least one sport in answer to the question "what sports do you participate in?" Photography, woodworking, music, gardening, reading, stamps, and home repairs followed next in order of popularity. A more detailed breakdown of his sports interests shows he prefers

TABLE 3.—COMMUNITY PROJECTS  
% Participation—45.5

Number of Activities per Participant...	1.6
Hours per Week per Participant.....	3.8
<b>Major Projects</b>	
Church .....	15.6
Civic Governments and Organizations .....	13.5
Youth Organizations .....	13.5
School Organizations .....	10.5
Fund Raising .....	8.3
Others .....	10.4

golf by a three to two margin over second-place swimming, then comes tennis, next hunting, fishing and hiking lumped together, and finally bowling, which attracts one out of five engineers. Following woodworking comes music. As it was on the sports question, music is not listed as a hobby by all the 39% who later in the questionnaire claim to play a musical instrument. Skipping over gardening to reading, the answers reveal that nearly every replier reads an average of 1.3 newspapers, preferring the New York Times and Herald Tribune. Life, Time, Readers Digest, and the Saturday Evening Post are the favorites in magazines with nearly every replier reading an average of two magazines. Readership of technical magazines is prevalent with 97% of the repliers listing 2.3 magazines. Of the group 93% read an average of twelve nontechnical books a year and 84% read an average of 4.6 technical books a year. Naturally, all of this reading is not hobby reading, but we have covered it in this spot because it is related. Television-viewing accounts for seven hours a week for the 65% of engineers who have sets and radio-listening accounts for five and one-half hours for 87% of the repliers.

Evidently, efforts made to interest the engineer in community activities have borne fruit, since 45% of the repliers listed 1.6 activities each, spending three and one-half hours a week on these activities. The major ones are church work, civic government, youth organizations, school organizations, fund raising, and others. (See Table 3.)

Concerning the professional activities of the repliers: All were members of the A.I.Ch.E. Next in order of frequency were the A.C.S. and A.A.A.S. A little more than a quarter of the group

TABLE 1.—NATIONALITY AND ORIGIN

Individual		Father	Mother
U.S.A.	94%	68%	73%
Canada	1.7	Russia	5.6
Germany	1.3	Germany	3.7
Others	3.0	Poland	3.2
		Italy	3.1
	100.0	Austria	2.0
		England	2.9
		Canada	1.9
		Others	8.6
		100.0	100.0

TABLE 4.—PROFESSIONAL ACTIVITIES

<b>Societies</b>	
Average Membership per Replier...	1.9
A.C.S. ....	56 %
A.A.A.S. ....	6.1%
<b>Patents</b>	
% Holding Patents .....	27.4
Average Patents per Holder .....	7.4

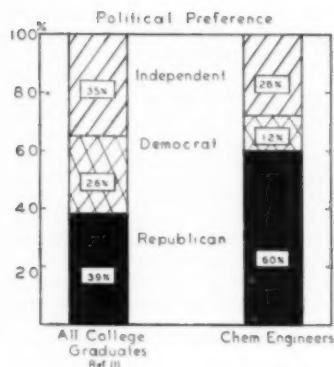


Fig. 2. Political preferences of chemical engineers.

held patents, an average of 7.4 patents a patentee.

Now for opinions: The political opinions of chemical engineers classify them among the most conservative element on the American scene. The accompanying Figure 2 illustrates a comparison between political preferences of college graduates in general and chemical engineers. As can be seen, 39% of all college graduates are Republican compared with 60% for chemical engineers. Only for a group of college graduates making \$7500 a year, and more than 55 years old, is the percentage of Republicans comparable with that of chemical engineers. Of timely interest is the preference of Presidential candidates. Eisenhower is the overwhelming favorite, Taft next, and Warren third. Of the repliers 10% preferred a Democratic candidate; this indicates that all those who listed themselves as Republicans and Independents (60% plus 28%) and a few of those listing Democratic (12%) selected a Republican candidate.

In answer to the question "Do you believe in God?" 85% replied "Yes," 7.6% replied "No," 4.9% were undecided, 1.7% agnostic, and 0.5% with other answers. This question was by far the most provocative. Answers ranged from "No doubt about it—yes" and "by all means" to "no—not in the usual sense" or "no—but I believe in the benefits of an organized religion." There is no figure for comparison on this question, but the general comment, I have heard from others, is that they think the affirmative figure is high. Some indication that this is so comes from Figure 3, which shows the frequency of attendance at various functions. The black bar shows once-a-week attendance, the cross-hatched once a month and several times a year, and the blank bar fewer than several times a year. It can

Frequency of Attendance

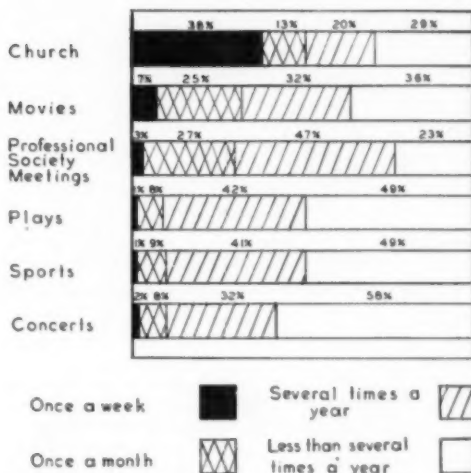


Fig. 3. Frequency of attendance of chemical engineers at various functions.

be seen that for church attendance, although there is an 85% belief in God—only 71% attend church more than several times a year. Church attendance is seen to be more popular than movie attendance, plays, sports, and concerts, however. More than one third of the engineers go to movies fewer than

several times a year and more than one half go to plays, sports events, and concerts fewer than several times a year. Professional society meetings show a peak in popularity of attendance for the frequency of several times a year with almost half of the repliers attending that often.

## HIS EDUCATION

### JAMES W. HEMPHILL

Johns-Manville Sales Corporation,  
New York, New York

WHERE did the chemical engineer of our survey come from? The data indicate that the chemical industry in the New York and New Jersey areas attracts engineers from practically all parts of the United States. Briefly, some forty states and the District of Columbia are represented in the survey. Figure 4 shows the survey distribution in the U. S.:

	Per Cent
East .....	61.5
Midwest .....	24.5
West .....	5.0
South .....	9.0

Approximately 3% of the total members



**JAMES WIL-LARD HEMP-HILL** is manager, chemical industry, Johns - Manville Sales Corp., New York. Born in Blairsville, Pa., he was graduated from the University of Pittsburgh with a B.S. M.E. and subsequently received a Master's degree in M.E. He is company representative in American Pulp & Paper Mill Superintendents Association and belongs to the Technical Association of the Pulp & Paper Industry. He also is a member of TAPPI.





Fig. 4. Where chemical engineers in New York-New Jersey area come from.

reporting came from Canada and other parts of the world.

**The Chemical Engineer and the Primary School.** Figure 5 indicates that 88% of the engineers received their primary training in public high schools and some 12% came from private schools. Statistically, these figures check quite closely with the national data on student enrollment in public and private high schools. In 1948 approximately 89.5% of the students were enrolled in public high schools and 10.5% in private high schools. In fact, it appears that the private school turns out more chemical engineers percentagewise than the public school. This conclusion must be balanced with the fact that on a percentage basis more graduates from private schools go to college than do students from the public high schools.

Our future engineer was quite a normal fellow during the formative high

school years. He entered readily into school activities, such as the year book, the school paper; into sports like fencing, skiing, tennis, baseball and swimming, which require skill and aptitude, and concerned himself with bettering his scholastic record, joining clubs that promoted the study of science and language. In short, he was in the top half of his class scholastically, socially and, where physically able, athletically. He was what is known in common parlance as an all-round student. Definitely a Phi Beta Kappa prospect, but not by any means a greasy grind.

**Our Engineer Goes to the University.** In most cases our engineer received his graduate degree from a school in the same state in which his high school was located. In other words, he did not start moving about until the question of getting a job came up, or he considered taking advance work toward a postgraduate degree. When selecting his school he preferred the background of a university to that of either a college or technical school. (See Fig. 6.) Probably this choice was made because of the wider scope of courses offered and the greater opportunity to associate with fellow students taking courses in other subjects than engineering.

**Bachelor and Postgraduate Degrees.** Approximately 95% of those engineers reporting, received a B.S. degree usually in chemical engineering. Less than 5% took liberal arts courses, and subsequently were awarded A.B. degrees. Most of those holding A.B. degrees were older men who had gone to college when the A.B. degree was still popular and chemical engineering was hardly known in the field of education. However, in almost every case these men stayed in school another year, were the recipients of a B.S. de-

gree and ultimately went on to get postgraduate degrees. Our engineer believes education is a continuing process.

Figure 7 shows that 56% of those reporting received one or more postgraduate degrees. The survey indicates that 38% of the total received M.S. degrees, 14% Ph.D. degrees and 4% either D.Sc. or D.Eng. degrees. While no substantiating statistics are available, it seems plausible to state that this group shows an exceptionally high percentage of men with postgraduate degrees.

In most cases our engineer received his postgraduate degree in a different school from the one which conferred on him his bachelor's degree. As to postgraduate schools, he showed a decided preference for the Eastern technical schools.

**College Sports.** The survey shows that approximately 70% of those reporting took part in college sports. Such sports activities, engaged in during the high school years, carried well into the engineer's college life. While interested in some of the intramural sports, it should be noted that he was essentially an individualist even in this field.

**Our Engineer Is Socially Inclined.** Our engineer is anything but a recluse; in fact, he is quite a joiner—fraternities, both local and national, were quite popular. Social clubs and local college groups, such as students' sections of the A.I.Ch.E., were freely listed. A high percentage reported affiliations with one or more honorary fraternities or societies. He favors clubs and fraternities because they give him the opportunity of developing associations and contacts that might otherwise be difficult to establish. However, a small minority who disliked college clubs and fraternities were definite in their points of view and felt that the college fraternity and club

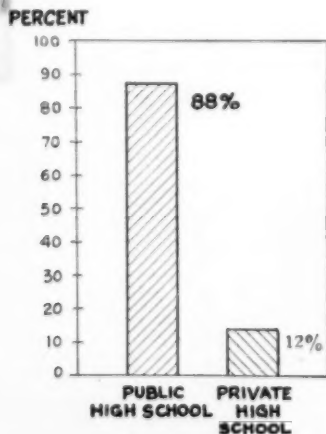


Fig. 5. Origin of high school training of chemical engineer.

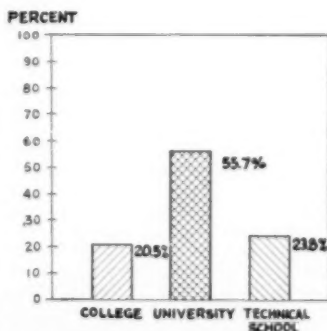


Fig. 6. Where our engineer took his graduate degree.

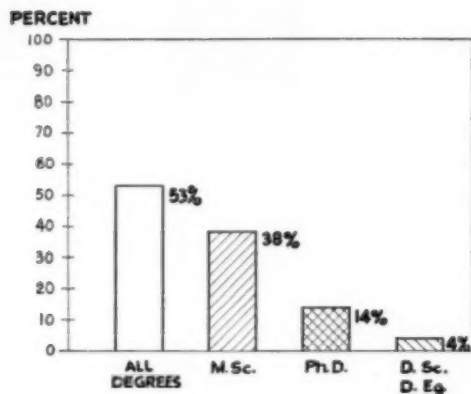


Fig. 7. Distribution of postgraduate degrees of chemical engineers.

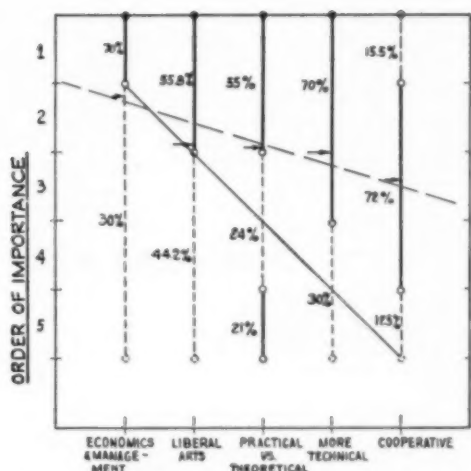


Fig. 8. Analysis of data of the suggested changes of engineering courses.

— on chart shows avg.  
 --- shows best avg. line (inspection).  
 = perfect agreement.  
 1/5 (20%) criterion of compactness.

were discriminatory and fundamentally undemocratic.

**Military.** There is little evidence that military training interfered seriously with our engineer during his college years. If he went to a land grant school where military training was compulsory, he naturally spent some time in the R.O.T.C. or similar basic training course. Otherwise, he did not take military training.

**Why Engineering?** Most of the answers to the question: "Why did you study chemical engineering?" might be considered basic. Reason mostly given was a liking for mathematics, chemistry and the sciences in general. Natural aptitude and ability in this field, plus the thought that a chemical engineer could always get a job and make a good living, were also noted as basic reasons.

**Are Engineering Courses Adequate?** A majority of engineers reporting on this question felt that the courses as given today are adequate and generally satisfactory, realizing that only so many courses can be given in the four years assigned for the completion of engineering work.

**Suggested Changes in Engineering Courses.** It is, indeed, regrettable that the committee was not more explicit in formulating our questions relating to the subject and that we did not have an opportunity to try out our questionnaire on a so-called "pilot group." Many reporting either failed to comment on this

group of questions, or did not take the trouble to rate them in the order of importance. It was quite evident that the question relating to cooperative courses was not understood by the majority. Referring to Figure 8, it can be noted that broader courses including business economics and management, were considered first in order of importance to engineers. Questions relating to more practical and less theoretical training and broader courses to include liberal arts, considered of about equal importance, took over the second and third positions.

The query on more technical training was supported by those engineers who had one or more postgraduate degrees and who evidently were interested in research work requiring the maximum of technical training. The majority rated the question of relatively low importance so that it fell into fourth place.

It was noted that the engineers who had had cooperative courses in their schools placed this kind of training high in the order of importance. However, the report of the majority was to rate it of least importance.

Several replies whose comments are worthy of ready listeners made the following suggestions:

- Give us better teaching staffs and techniques.
- Eliminate all descriptive courses. Stick strictly to fundamentals. When they are known, all variations will easily be acquired.
- Offer a course in statistics.

**Should Engineering Courses Be Lengthened?** The majority of engineers reporting on this question held the view that all engineering courses should be extended to five years instead of the conventional four. Also, a great many of them suggested that this additional year should be spent primarily in broader courses to include business economics, management and liberal arts. There was also a request for more practical and less theoretical training. This phase of the survey ties in quite closely with the recommended changes in engineering courses which included all these factors as matters of prime importance. A relatively few felt that the engineering courses should be extended to six years. Once again the minority report is interesting in its opinion that a four-year course was sufficiently long and if the college, university or technical school had done its job, namely, to teach a man how to study and the student in turn grasped the fundamentals, much more could be gained by spending these years in industry than in school. There, of course, is much to be said on both sides of this issue.

**Should Teachers Be Consultants?** The great majority favored having teachers who did some consulting work in addition to their teaching. It was felt that by doing this outside work, the teacher came in closer contact with industry and was in a better position to keep abreast of the advances being made. It was also contended that the consulting

work adds to the teacher's interest in his teaching and helps hold him in this field of effort, where there is already a definite shortage.

The report of the minority group again proves helpful in that it brings out the fact that many of the teaching consultants are too busy consulting to

do a reasonably good job of teaching. It pointed out that many of the big-name teachers who are prominent in the consulting field, rarely, if ever, come in contact with the student. The minority pointed out that the fundamental responsibility of a teacher should be teaching and not consulting.

## HIS SALARY

W. T. DORSHEIMER

Stamford, Connecticut



**WESLEY T. DORSHEIMER** is employed as a sales engineer in the petroleum chemicals division of the Du Pont Co., Wilmington, Del., which he joined in June of this year. He was graduated from Carnegie Institute of Technology with a B.S. in chemical engineering. His first industrial association

was with Esso Standard Oil Co., in its technical service division. Then followed a period of three and one-half years with the Navy as Ensign to Lieut. U.S.N.R.—chief engineer on destroyers. After the war he was employed as a sales engineer by C. F. Braun and Co., Alhambra, Calif., and later as assistant sales manager of the chemical industries division of the Foxboro Co., Foxboro, Mass.

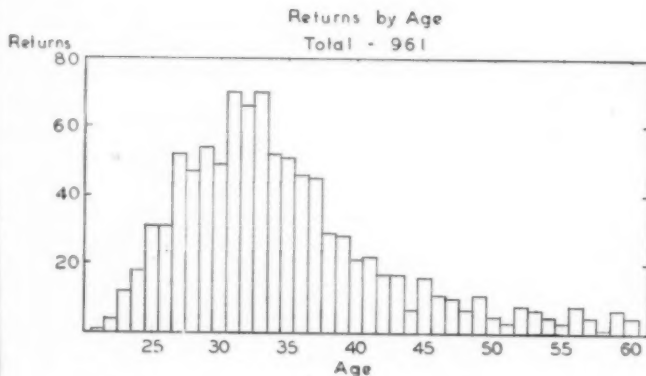


Fig. 9. Returns by age of usable questionnaires in salary survey.

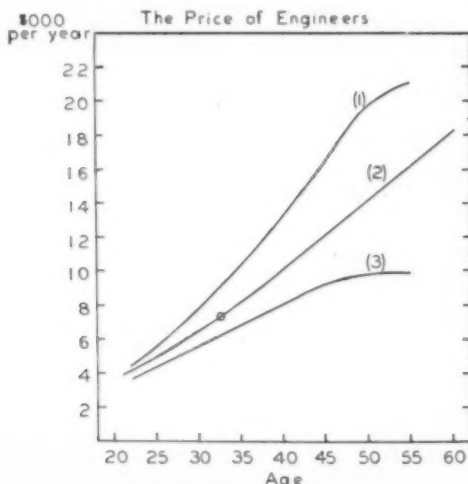


Fig. 10. Price of engineers.

(1) 80th Percentile.  
(2) Median.

(3) 20th Percentile.  
○ Median of all returns.

**T**HIS paper will discuss the results of the survey questions pertaining to past and present salaries.

Figure 9 reveals a total of 961 usable returns and the number of returns for each age. Most returns were from men in their late twenties and early thirties. The median age of all returns was 33. In plotting the results of this survey, median salaries and ages were used throughout. The median, it will be recalled, is the point in an array of data above and below which exactly half the series is located. The median is more significant than the average salary in a survey of this type, because the median is not unduly affected by salaries that are either very high or very low. Also, use of the median allowed for the inclusion of such answers as, "Present salary above \$25,000."

The salary picture is presented in Figure 10. On this graph, median salaries, as well as 20th and 80th percentiles, are plotted against age. These salary figures do not include bonuses or overtime. Salaries for men more than sixty were not included, because there were few returns from engineers over this age, and of these few, most were from men partially retired. As shown in Figure 10, the median yearly salary of all 961 returns was \$7,300. The median curve passes through the following points, and is almost a straight line:

Age	Salary †
25	\$4,800
30	6,500
35	8,200
40	10,000
45	12,000
50	14,000
55	16,000
60	18,000

† The median raise is \$2,000 every five years, or \$400 per year.

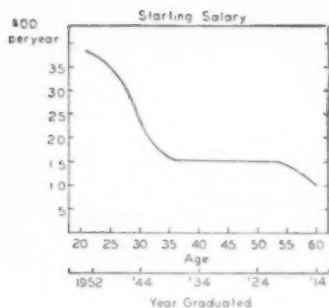


Fig. 11. Starting salaries.

The 80th percentile curve climbs at quite a steep rate until it reaches age 50, and then it begins to taper off. At age 50, the man on the 80th percentile curve is making appreciably more than the median: \$20,000 compared with \$14,000. The 20th percentile levels off at about age 46, and it never quite reaches \$10,000. It might be well to remind the reader that these curves are based on all usable returns, including those of teachers.

A recently published book entitled "They Went to College," (see p. 42 this issue) contains some enlightening facts. Results of our survey compared with salary information published in this book show that the responders to our survey make more than any other profession, except for medical doctors. We make more than dentists and lawyers, and although medical doctors make more in the younger years, their median salary curve starts tapering off in the forties and, eventually, the chemical engineer makes more even than the M.D. It should be kept in mind, however, that our survey covers only the New York area, whereas the salaries published in "They Went to College" cover the entire country, and quite probably New York area salaries are higher than figures based on the entire United States.

The last survey of chemical engineers in the Greater New York area was taken in 1949 and published in Chemical Engineering in July of that year. Both that survey, and a previous one taken in 1947, showed a salary dip for the Class of 1938. Both surveys reported that the Class of 1938 median salary was lower than the Class of 1939; the explanation given was that 1938 was a year of economic recession. The present study does not show such a dip, possibly because it was based on almost three times as many returns as the 1949 survey, or, possibly because the current shortage of engineers has eliminated any "depression effect."

Some interesting results were found in the answers to the question on starting salary. (See Fig. 11.) Starting salaries increased during both World War I and II, and remained constant for the twenty years between the two wars. It is well known that beginning salaries have continued to climb for the past two years, but there were insufficient returns from the last two graduating classes to show the magnitude of this increase.

How do 1952 salaries compare with other years? Figure 12 compares the median salary data from this survey with the results of the 1949 survey of young chemical engineers (same New York area) referred to above. As evident, there has been only a slight increase in the past three years. Directly comparable figures for the older chemical engineers were not available, but Figure 12 does show (curve on lower

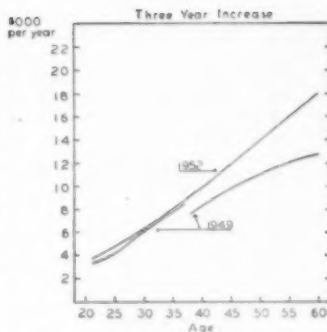


Fig. 12. Comparison of three recent salary studies.

right in Figure 12) a compilation of a 1949 survey of active A.I.Ch.E. members for the country as a whole.

## HIS SALARY VARIATIONS

MASON L. DOWNING

Scotch Plains,  
New Jersey



M.I.T. as a student, and then served as an instructor in the School of Chemical Engineering Practice, and received his M.S. degree in chemical engineering in 1947.

MASON L. DOWNING has been doing chemical engineering work in New Jersey since 1947. After graduation from Massachusetts Institute of Technology, Cambridge, Mass., in 1941, with a B.S. degree in chemistry, he served four and one-half years in the Army. He returned to

be used in preparing these results, they came only from the "cream of the crop" of chemical engineers—members of the A.I.Ch.E. The group covered was restricted further to those who had sufficient ambition to fill out the questionnaire. Thus, it can probably be concluded that if these salary data are in error, they are slightly on the high side.

Of course, we all have our own private reasons for thinking that our own salary isn't quite so high as it should be. For example, many of us have griped at times that our loss of several years to the military service has caused us to suffer salarywise compared with others. Figure 1 punches a pretty big hole in that story.

THE first reaction of most chemical engineers on seeing a result they don't expect is usually "There's something wrong with the data." Perhaps some of the 80% of my readers whose salaries fall below the top line on the accompanying Figure 13 are doubting Thomases. This author would like to record some of the ways we've looked at the data.

First, it is recognized that the data have limitations. Although about 1000 questionnaires were received in time to

There salary in thousands of dollars a year is plotted vs. age. The dotted curve is the smoothed median salary curve for all groups as obtained in this present study. The broken line shows the actual data point for all age groups. The 30-to-40 age group was the only one with sufficient military service returns for consideration—142 men with military service or about 25% of the returns for that group. The round points on the plot are median salary—median age points for the 30-35 and 35-40 age groups. It

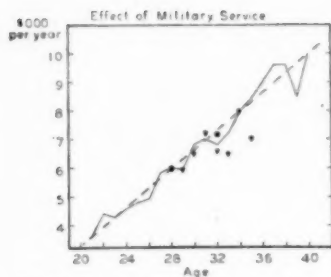


Fig. 13. Effect of military service on salary of chemical engineers.

● Median all groups.  
▼ 10-year medians { Mil. Serv.  
1-year medians {

should be noted that both points fall right on the curve. Even breaking down the returns to single-year age groups as shown by the upside-down triangles yields no significant variation from the median curve. The low point at age 35 represents only eight returns whereas ages 31 and 32 each had more than thirty returns. Actually all sorts of groupings were tried—those with more than two years' service, those with more than three years', and those with more than four years' and in every case no significant variation was found from the median curve.

**Company Size.** Another cause frequently advanced for salary variation is size of company. People who work for big companies say "You make more

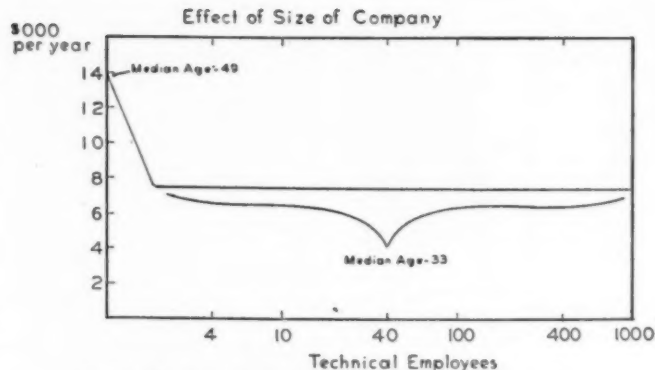


Fig. 14. Effect of size of company on median salary of chemical engineers.

money in a small outfit but I like the security of a big company," or if they work for a small company, they say "You make more money if you work hard in a big company but you have more independence in a small company." Figure 14 shows the effect of size of company. Median salary is plotted vs. number of technical employees. Median ages are indicated. It should be noted that the median salary of \$7500 a year with 33 years of age is constant regardless of size of company all the way from two to more than 1000 technical employees. The only exception is companies with one technical employee. They jump suddenly to \$14,000 a year. However, the median age also jumps to

49. That combination of salary and age puts them right back on the median salary curve.

So it looks as though neither size of company nor military service makes any difference in median salary. Next for consideration is the field of occupation. That does make some difference.

Figure 15 shows salary vs. age and the median salary curve. Separate median age, median salary points are plotted for each occupational group. It can be seen that research and development and design fall right on the median salary curve. Sales and sales engineering also fall right on the curve, which destroys another illusion that the salesmen make all the money. The men working in production appear to be a little on the low side, but as expected, it is the teacher who takes the beating salarywise. Teachers are a long way below the curve. Administrators are a bit above the curve. This includes all those who consider themselves administrative even though their principal duties may be technical. About 200 of those answering the questionnaire considered themselves administration or more than 20% whereas a previous survey indicated that 11.6% of chemical engineers actually work principally as administrators. The other field well above the curve is that of consulting and this is probably to be expected. Also of interest is the percentage of total returns falling in the various occupational categories. The breakdown was as follows:

Work Categories	Per Cent
Research & Development	34
Teaching	3
Sales & Sales Engineering	6
Production	12
Administration	21
Design	15
Consulting	1
Other	8

The expectations of chemical engi-

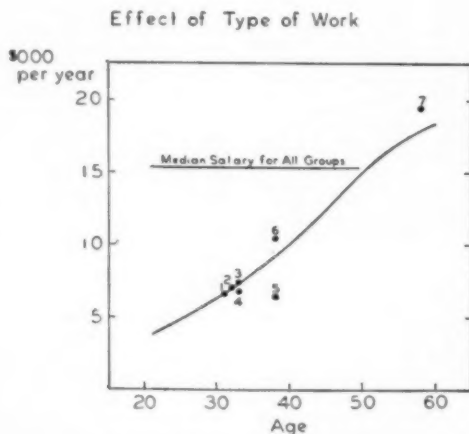


Fig. 15. Effect of type of work on salary.

1. Research and development.
2. Design.
3. Sales and Sales Eng.
4. Production.
5. Teaching.
6. Administration.
7. Consulting.



neers are shown in Figure 16. On the same plot of median salary vs. median age (shown as line 3) curves have been included to show what engineers expect to be making in ten years (line 2) and what is expected eventually (line 1). The ten-year curve indicates that most of us have a pretty fair idea of what we can expect to be making ten years from now. If this curve were moved to the right by ten years it would fall nearly on the median salary curve. It is interesting to note that the older we become the more optimistic we become. The guesses of the 40-year olds are above the median for age 50 by a couple of thousand dollars whereas the ten-year guesses of the 25-year olds are pretty close to the salary of 35-year olds.

It looks as though we are not nearly as good at guessing what salary we might be making eventually. This step-

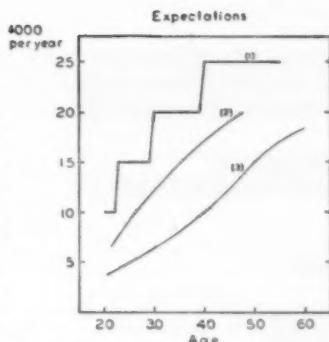


Fig. 16. What the chemical engineer expects in salary.

- (1) Eventually.
- (2) In 10 years.
- (3) Now.

IT IS one thing to measure a man's background, training and present status—it is quite another to measure his hopes and ambitions for the future. In a study such as this survey, the tangible accomplishments of an individual to date provide a sound objective basis for a statistical evaluation. It is difficult for even the most subjective person to depart from the record in describing his past experience and his present situation.

But when great expectations are to be measured, all the stops are out. The dreamer's ambitions demand the same statistical respect as those of his less imaginative and possibly more "bearish" colleague. An expressed desire to own an ocean-going yacht or become the president of a major industrial concern must be accepted in the same light as the more easily realized ambition of owning an outboard motor or advancing to the next immediate position on the management ladder.

As a result, about the only approach that could be used in a study of the Hopes and Ambitions part of this survey was that of correlating the answers given with age. This is in line with the long-established observation of psychology that an individual's motivations change with age. In general this observation was borne out by the findings of this survey. But at the same time some indications developed that tended to show that this change might not be just a function of absolute age but also of the particular era in which an individual formed his long-term attitudes toward his career and his life in general. In other words it might be more a question of a man's being "older-fashioned"

than older in his response to a given question.

The 1,015 returned questionnaires used in this study were divided by age groups as follows:

Group A (30 years and under) ..	318
Group B (31-40 years, inc.) .....	478
Group C (more than 40 years) ..	219

Although, as noted in other sections of the survey, the 31-40 group returned the greatest number of questionnaires, it was felt that the division shown here represented a fair sampling of the age groups studied.

**Material Possessions and Ambitions.** As a glance at Figure 17 will show, chemical engineers are well endowed with automobiles. More than 90% in all three age groups own cars and only in the case of the oldest group does the figure of those who want to buy a car within the next ten years, when added to the present ownership, fail to equal or pass 100%. In the other two groups the fact that present ownership plus future ownership amounts to more than 100% is accounted for by the ambition

shaped curve should be a straight horizontal line at perhaps \$22,000. The 20-30-year olds don't appear to realize how much money they can make even if they just keep on being median individuals. Ages 30-40 guess pretty close to their actual ceiling and surprisingly enough the 40-50-year olds, if anything, are overoptimistic about their eventual salaries.

Thus, to summarize—it looks as though neither military service nor size of company has any significant effect on how much a chemical engineer is paid. The choice of field has some effect but except for teaching the effect is small.

Although the conclusion may be somewhat disappointing to some of us, it appears that ability and hard work play a more important part in deciding our salaries than all of the above-mentioned factors combined.

## HOPES AND AMBITIONS

RICHARD L. DEMMERLE

General Aniline and Film Corporation  
New York

of many engineers to own two or even three automobiles.



**RICHARD L. DEMMERLE** is assistant director of administration of General Aniline & Film Corp. Prior to his present position he was executive editor of *Chemical Week* and before that association was an associate editor of *Chemical & Engineering News* and *Industrial & Engineering Chemistry*. During World War II, Mr. Demmerle served as an administrative official of the Division of War Research of Columbia University, a vital part of the Manhattan Project.

Mr. Demmerle is a graduate of Columbia ('40) where he majored in chemistry. He is a member of many societies and a frequent author of articles on the subject of human relations. Mr. Demmerle is the chairman of the symposium, "Human Relations," which will be given at the December meeting of the A.I.Ch.E. in Cleveland, Ohio.

Ownership of a house correlates well with the age of the individual, the great-

# MATERIAL POSSESSIONS & AMBITIONS OF ENGINEERS

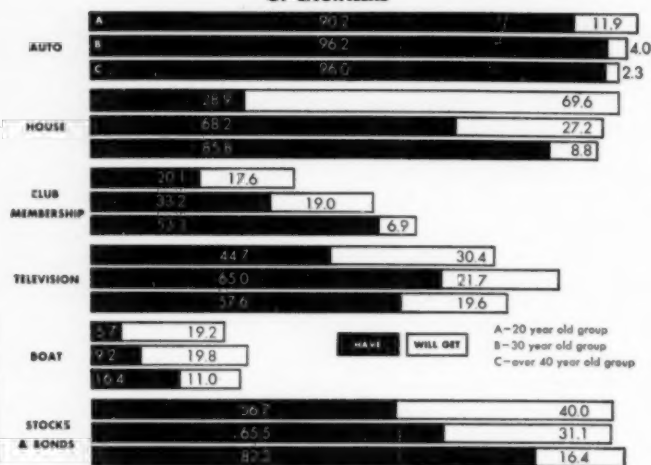


Fig. 17. Material possessions and ambitions of engineers. (Shown percentage-wise.)

est house-owning group being the oldest, where more than 85% own homes. By the same token the youngest group, who percentage-wise own the least number of houses, express the greatest percentage desire to buy homes.

The actual holding of memberships in social clubs follows the same pattern observed in the case of automobiles and houses—an increase with age. But a deviation from the pattern is noticeable in the percentages of the various age groups expressing a desire to become a member of a social club within the next ten years. The youngest group, who should be the most ambitious in this regard, are surpassed by the middle group. Exactly 19% of the latter express the intent to join a club within the next ten years, whereas only 17.6% of the youngest group indicate this feeling.

Another deviation from the pattern of increased ownership with age is found in the case of television ownership, heavy in the youngest group (44.7%), heaviest in the middle group (65.0%) and slacking off in the oldest group (57.6%). Similarly, the oldest group shows the least percentage desire (19.6%) to buy a television set if one is not already owned.

Boat ownership is small throughout all age groups, reaching its highest point with Group C (16.4%). As in the case of club memberships, the men in their thirties show a disproportionately greater desire to buy a boat if one is not already owned.

The ownership of stocks and bonds is high throughout all age groups, and

follows the general trend to be largest in the oldest group. The intent to buy more stocks and bonds also follows the general pattern by being strongest in the twenty-year olds.

**Foreign Travel.** Chemical engineers are well traveled, many of them by virtue of service in the Armed Forces, with government agencies or by assignment from their companies. Exactly 84% of Group A, 88.6% of Group B and 93.6% of Group C have been outside the continental United States. Canada is the area most frequently visited; 50.9% of Group A, 64.6% of Group B and 74.0% of Group C have all visited our northern neighbor.

Europe is named by all three groups as the next most frequently visited area and Central America, including the West Indies and Cuba, occupies third position. Travel to the Far East, Australia, the Pacific Islands and Hawaii is cited more frequently by Groups A and B than it is by C, presumably because of service in World War II.

Future travel desires of all three groups most frequently mention Europe as the first choice of a place to visit. This feeling is strongest in Group A (53.8%). South America has undisputed position of the second choice of a place to visit in the travel plans of all three groups but is strongest percentage-wise among members of Group C (26.4%). Hawaii and Canada, in that order, occupy third and fourth positions in the travel ambitions of all three groups.

**Foreign-Language Interests.** When

asked whether they possessed a fair reading knowledge of a foreign language, the three age groups answered affirmatively as follows:

Age Group	Per Cent
A	57.5
B	51.5
C	65.8

When asked to name the language or languages in which they would most like to initiate or extend their proficiency, German was named most frequently by all three groups. French was named by all three groups as the language of second choice, and Spanish, Russian and Italian for third, fourth and fifth choices respectively.

It is interesting to note, however, that Spanish and Russian tie for third position in the ambitions of the youngest group at 19.7%. A desire to learn these two languages is widely separated in the ambitions of the oldest group where 30.5% favor Spanish and only 11.4% name Russian. It is possible that this situation may stem from the fact that when the older men were receiving their education, Spanish was highly touted as the language of international business. It is also possible that recent international affairs and a corresponding heightened interest in Russian technological developments caused many of the younger men to mention Russian as a language for study.

**Marriage Status and Family Ambitions.** The survey reveals that a predominant majority of chemical engineers are married: Group A—71.8%, Group B—91.2%, Group C—97.8%. Of the married members of Group A, 45.5% have no children, 15.7% one daughter and no sons, 11.2% have one son and no daughters and 7.0% have one son and one daughter.

In Group B the one-son and one-daughter combination is the most frequent family size (21.1%). Almost 16% have no children and 12% have a son and 10.3% have one daughter. In Group C the one son and one daughter family size is the most common (15.3%). Next in frequency are the fathers of one daughter (11.5%) and the fathers of one son (10.6%).

When asked about the size of family desired, all three age groups of married men answered the same: two sons and two daughters. A family size of two sons and one daughter was named next most frequently in Group A. Groups B and C feel that one son and one daughter is the second most desirable family group. It is interesting to note that about 10% of the married men in each of the three age groups expressed a desire for five or more children.

A surprising uniformity of opinion through all age groups, including unmarried men, was observed in the answer to the question of whether they would like to have a son become an engineer. A negative answer was received from 13.6% of Group A, 12.5% of Group B, and 11.5% of Group C. Among those who offer a preferred or alternate choice of a profession for their sons, medicine is by far the predominant choice. Law runs a poor second in Group A as does business in Groups B and C. Of passing side interest is the fact that several members of Group C volunteered information on the profession of their adult sons. Of these men, 40% have sons who are engineers in one field or another and only 4% have sons who chose medicine as a career.

**Arts, Sports and Hobbies.** When asked to name the esthetic fields in which they would most like to develop or extend their interests, all three age groups named music most frequently, literature next and arts least.

Golf is the sport of first choice in all three groups being somewhat more popular in Group C. Boating is the next most popular and tennis rates third place among Group A and fourth place among members of Groups B and C. Fishing occupies third place in the participating sports interest of these two latter groups.

Photography is the most popular hobby among members of Group A and is followed by shopwork of one sort or another (wood-working, metal-working, etc.). Shopwork is the first choice of members of Groups B and C where photography drops to second place. Electronics (and radio) is the third most popular hobby among the youngest group just as gardening is with Groups B and C.

It is interesting to note that thirty-one different hobbies were named by engi-

neers responding to this part of the survey.

**Attitude Toward Politics.** A desire to enter political life is strongest among young engineers. More than 30% of this group express an interest in entering politics whereas 21.5% of Group B and 13.7% of Group C feel an urge toward the political arena.

**Attitude Toward Occupation.** The survey shows that the percentage of chemical engineers who are in business for themselves increases with age: 1.8% of Group A, 5.1% of Group B and 19.7% of Group C. A surprisingly large percentage of those not in business for themselves indicate a desire to be so: 70.0% of Group A, 64.2% of Group B and 49.0% of Group C.

In spite of this latter observation the overwhelming majority of all three groups claim they are either happy or reasonably happy in their present work. Discontent is greatest among the youngest group where 3.5% say they are not happy. This figure falls off to 2% in Group B and 0.5% in Group C.

More than 20% of both Groups A and B, however, feel they would like to employ their technical training in sales work rather than in their present occupation.

**Material Progress and Personal Life.** The last two questions in the "Hopes and Ambitions" part of the survey asked the engineers (1) whether they felt their material progress to date has been excellent, average or unsatisfactory and (2) whether their cultural and personal life to date has been rewarding, average or lacking.

Slightly more than 36% of Groups A and B answered "excellent" to the first question and about 50% of the same groups answered "rewarding" to the second question. In Group C, 49% answered "excellent" to the first question

and slightly more than 64.2% answered "rewarding" to the second. In Group A, 11.9% answered both "excellent" and "rewarding" as did 20.6% in Group B and 34.6% in Group C.

One of the most interesting observations in this section of the survey is made when the questionnaires on which both "excellent" and "rewarding" have been checked in answer to the aforementioned questions are studied separately. A positive correlation is found between the frequency of this joint answer and men who are either (a) in business for themselves, or (b) men who are not in business for themselves and do not wish to be.

Perhaps this is just another confirmation of the psychologists' oft-repeated statement that the best adjusted individual is the happiest, or the philosopher's observation that happiness is more a question of a man wanting what he gets rather than getting what he wants. In any event, the pursuit of happiness continues unabated.

## POSTSCRIPT

As a check on the salary data accumulated and reported here, Chemical Engineering Progress sent to several chemical companies the salary graph showing the median, the 20th and 80th percentiles. The companies were invited to submit comparable salary data in order that "C.E.P." might compare salary experience for all engineers over the country with the experience reported by the engineers from the New York and New Jersey areas. The results which were obtained from this second independent survey of companies are shown as curve 2 in Figure 18. Curve 1 is the median salary experience already reported in the preceding articles. As was to be expected, curve 2 is lower, since it represents firms outside the New York Metropolitan area, and also covers non-members of the A.I.Ch.E. However, considering all these circumstances, the agreement is quite good.

While the number of firms represented is necessarily small, the curve represents the salary experiences of many engineers. The lower salaries for the older engineers is difficult to explain, but possibly the majority of A.I.Ch.E. members at these ages are company executives.

Thus, an A.I.Ch.E. questionnaire would get data of men in the executive division of the industry, while company reports might consider these men as executives and not report their income, in a survey, as being earned by an engineer.

—F.J.V.A.

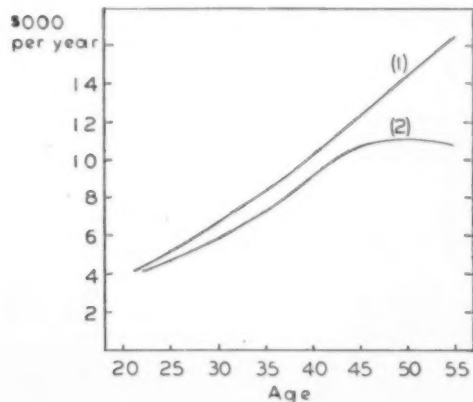


Fig. 18. Comparison of median salary results reported by A.I.Ch.E. members and data from the companies on employed chemical engineers regardless of affiliations.

(1) Survey.  
(2) Company.

# PLASTICS EQUIPMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER

The Atlas Mineral Products Co., Mertztown, Pa.

**POLYESTER-GLASS LAMINATED PLASTICS:** Glass reinforced structures based on polyester resins are available as tanks, tank covers, fume hoods, pipes, ducts, and various tailor-made equipment. The thickness and the type of reinforcement depend upon the size and end use of the equipment.

or slightly elevated temperatures. Structures are usually prefabricated or assembled on the job using flange-type assembly methods or by cementing sections with room temperature curing polyester cements and glass fabric.

**CHEMICAL COMPOSITION:** 25 - 40% unsaturated polyester-styrene or di-

allyl ester resin and 60 - 75% glass fabric or glass mat reinforcement.

**MACHINABILITY:** Depends upon nature of reinforcement. Glass cloth reinforced resins demand special techniques, but with glass mat, routine operations such as sawing, blanking, shearing, drilling, tapping, sanding and punching, can be carried out with ordinary machine shop equipment.

**TEMPERATURE LIMITATIONS:** 350-400° F.

**APPLICATION AND REMARKS:** Equipment may be molded with little or no pressure at ordinary

## MECHANICAL AND PHYSICAL PROPERTIES:

Tensile Strength, lb./sq.in. @ 75° F.	10,000
Impact Resistance, Izod	10-35 ft.-lb./in. of notch
Hardness, Rockwell	M 90-M 110
Flexural Strength, lb./sq.in.	20,000-60,000
Compressive Strength, lb./sq.in.	30-60,000
Modulus of Elasticity (x 10 <sup>6</sup> lb./sq.in.)	10-28
Specific Gravity	1.5-2.1
Specific Heat (B.t.u./lb.) (° F.)	0.2-0.25

## CORROSION RESISTANCE

	Cold (75° F.)	Hot (200° F.)		Cold (75° F.)	Hot (200° F.)		Cold (75° F.)	Hot (200° F.)
<b>ACIDS</b>								
Acetic, 10% .....	E	G	Ammonium Cl, NO <sub>3</sub> , SO <sub>4</sub> .....	E	E	Refinery Crudes .....	E	E
Acetic, glacial .....	E	N	Copper Cl, SO <sub>4</sub> .....	E	E	Trichloroethylene .....	N	N
Benzene sulfonic .....	E	E	Ferric Cl, SO <sub>4</sub> .....	E	E	<b>PAPER MILL APPLICATIONS</b>		
Benzoic .....	E	E	Nickel Cl, SO <sub>4</sub> .....	E	E	Kraft Liquor .....	N	N
Boric .....	E	E	Stannic Cl .....	E	E	Black Liquor .....	N	N
Butyric .....	E	E	Zinc Cl, SO <sub>4</sub> .....	E	E	Green Liquor .....	N	N
Chloroacetic .....	P	N	<b>ALKALINE SALTS</b>			White Liquor .....	N	N
Chromic 10% .....	E	N	Barium Sulfide .....	G	N	Sulfite Liquor .....	E	E
Chromic 50% .....	P	N	Sodium Bicarbonate .....	N	N	Chlorite Bleach .....	E	E
Citric .....	E	N	Sodium Carbonate .....	N	N	Alum .....	E	E
Fatty Acids (C <sub>8</sub> and up) .....	E	N	Sodium Sulfide .....	G	N	<b>PHOTOGRAPHIC INDUSTRY</b>		
Fluosilicic .....	E	N	Trisodium Phosphate .....	G	N	Developers .....	E	F
Formic .....	P	N	<b>NEUTRAL SALTS</b>			General Use .....	E	E
Hydrobromic .....	E	E	Calcium Chloride .....	E	E	Silver Nitrate .....	E	E
Hydrochloric .....	E	E	Calcium Sulfate .....	E	E	<b>FERTILIZER INDUSTRY</b>		
Hydrocyanic .....	E	E	Magnesium Cl, Sulfate .....	E	E	General Use .....	E	E
Hypochlorous .....	E	E	Potassium, Cl, NO <sub>3</sub> , SO <sub>4</sub> .....	E	E	<b>STEEL</b>		
Lactic .....	E	E	Sodium Cl, NO <sub>3</sub> , SO <sub>4</sub> .....	E	E	Sulfuric Acid Pickling .....	E	E
Maleic .....	E	E	<b>GASES</b>			Hydrochloric Acid .....	E	E
Nitric 5% .....	E	E	Chlorine wet .....	E	F	H <sub>2</sub> SO <sub>4</sub> -HNO <sub>3</sub> Pickling .....	E	P
Nitric 20% .....	E	E	Chlorine dry .....	E	E	<b>TEXTILES</b>		
Nitric 40% .....	E	E	Sulfur Dioxide wet .....	E	E	General Use .....	E	E
Oleic .....	E	E	Sulfur Dioxide dry .....	E	E	Hypochlorite Bleach .....	E	P
Oxalic .....	E	E	Hydrogen Sulfide .....	E	E	<b>FOOD</b>		
Perchloric .....	E	E	<b>ORGANIC MATERIALS</b>			General Use .....	E	E
Phosphoric .....	E	E	Acetone .....	N	N	Breweries .....	E	E
Picric .....	E	E	Alcohols .....	E	E	Dairies .....	E	E
Stearic .....	E	E	Aniline .....	E	E	<b>MISCELLANEOUS INDUSTRIES</b>		
Sulfuric 50% .....	E	E	Benzene .....	E	E	Plating .....	E	G
Sulfuric 70% .....	E	E	CCl <sub>4</sub> .....	E	E	Petroleum .....	E	E
Sulfuric 93% .....	E	E	Chloroform .....	E	E	Tanning .....	E	E
Oleum .....	E	E	Ethyl Acetate .....	N	N	Oil and Soap .....	E	E
Mixed Acids .....	F	N	Ethylene Chloride .....	N	N	Water and Sewer .....	E	E
<b>ALKALIES</b>			Formaldehyde, 37% .....	E	E			
Ammonium Hydroxide .....	F	N	Gasoline .....	E	E			
Calcium Hydroxide .....	F	N	Phenol .....	N	N			
Potassium Hydroxide .....	F	N						
Sodium Hydroxide .....	F	N						
<b>ACID SALTS</b>								
Alum .....	E	E						

### RATINGS:

E—No attack.  
G—Appreciably no attack.  
F—Some attack but usable in some instances.  
P—Attacked—not recommended.  
N—Badly attacked.

## No. 12

(IN A SERIES  
ON CORROSION  
RESISTANT  
MATERIALS)

# CENTENNIAL OF ENGINEERING



## INSTITUTE MEETS IN CHICAGO, SEPTEMBER 11-13

**E**NGINEERING science of every description will join in a centennial of engineering in Chicago next month, in honor of the 100th anniversary of the founding of the American Society of Civil Engineers.

The American Institute of Chemical Engineers will play a prominent part in the celebration, and has scheduled a national meeting beginning Thursday, Sept. 11 and ending Saturday, Sept. 13. The program of the chemical engineers will feature various symposia and general technical sessions. Headquarters hotel for the chemical engineers will be the Palmer House.

In honor of the centennial the meeting will begin with a special symposium designed to illustrate the contributions to the Chicago area by chemical engineering. It will feature discussions of the petroleum, industrial carbon, the packing industry, as well as papers on individual chemical engineering subjects.

A second symposium will cover the new technique of mixed bed ion exchange and emphasis will be placed on the complete technique from theory down

to its possible application as a domestic softening unit.

The third symposium is on the subject of distribution of chemicals and is under the direction of Henry Dahlberg, International Minerals & Chemicals

Corp., Chicago, Ill., and R. M. Lawrence of the Monsanto Chemical Co., St. Louis, Mo. Transportation, packaging and sales will all be covered in a four-paper coverage of the subject.

As far as the general technical program is concerned, the whole field of chemical engineering is its subject, ranging from waste disposal problems, the fluidization technique in the petroleum field, discussions on drying problems, and hydrocarbon constants. The complete program is printed on pages 22 and 23 of this issue.

### Tours, Banquet, Exposition

The business part of the entertainment shapes up as follows: A series of tours through Chicago's chemical industries is planned. A modern research laboratory will be included in the program. The main banquet of the Centennial of Engineering Celebration will occur on Wednesday evening, Sept. 10.

*(Continued on next page)*



D. A. Dahlstrom, chairman, Technical Program.

*Article written by T. A. Matthews, II, Pure Oil Co., Crystal Lake, Ill.*



Tickets to this event will be available. The Annual Exposition of the American Chemical Society will be held at Chicago's Coliseum. The Exposition can be attended Thursday evening, Sept. 11.

### Chicago—The City

When visitors go to Chicago, for whatever ostensible purpose contrived, their chief thought is to see the sights and sample the many forms of diversion provided. Therefore, the planned entertainment for this meeting has been scheduled to provide a maximum of opportunity for "seeing Chicago."

"It's vast, it's exciting, it's different—It would take a lifetime to see it all."

Everyone planning to come will have a good time. Some come to shop and to see the sights, others to enjoy the shows, indoor and outdoor sporting events, celebrated restaurants, museums and art galleries, or the comforts of a luxurious hotel. Many come for a change in their daily routines, and no one is disappointed.

Every year almost twenty million people visit Chicago. They find something interesting to see and to do . . . all of the time.

If this is your first visit to Chicago, the thought of seeing the big city sends your pulse beat upward. You are pleased and excited—and why not? Chicago is a delightfully exciting place. Excitement rides the skyways over the Chicago Municipal Airport, where giant airliners arrive or depart, one every two and one-quarter minutes. Excitement hovers about the trains which rush in and out of the city, 1,770 every day. Excitement permeates the loop, rising and falling to the beat of millions of feet as Chicagoans hurry about whatever they may be doing at the moment.

You know in advance that Chicago is the world's fourth largest city and that it covers a lot of ground. Even so, it is much larger than you thought. If you arrive by air, you find the city stupendously vast, radiating fanwise from a blue inland ocean into the mists of far horizons with never a break in the "built up" pattern. If you come by train or automobile, the feeling of vastness is even more intense. Chicago, you discover, is something more than a city with corporate boundaries. It is an empire, a super city which would be more precisely described as Greater Chicago or "Chicagoland." It reaches into the adjacent states of Indiana and Wisconsin, encompassing fifteen counties and 285 villages, towns, and smaller cities. These communities depend largely on Chicago for their economic existence. They are spun into the main body of the metropolis by a webbing of rail-



Left: W. E. Brinker, co-chairman, Chicago Symposium, and right: J. S. Wilson, chairman, Entertainment Committee.

roads, bus lines, electrical interurban transportation systems, and auto highways.

It is Chicago which gave to the world its first steel frame skyscraper, its first Pullman car, its first grain reaper, its first atomic chain reaction.

Abraham Lincoln was nominated for the Presidency here, as were also Grant, Garfield, Cleveland, Harrison, Theodore Roosevelt, Taft, Harding and Franklin Roosevelt.

The city is the world's leading railroad center, meat-packing center, printing center, and grain-trading center. It produces approximately 47% of the nation's candy; 43% of its radio and radar equipment; 17% of its steel and packing-house products; 11% of its printing.

Almost one million persons are employed in Chicago area industries; all persons gainfully employed total approximately two and four-tenths million.

The Indians used the word Chicago to define something "great" or "strong." Perhaps there was something prophetic in their application of the name to this particular region.

The city's present population is in excess of 3,600,000. The population of the metropolitan area is five and one-half million.

It is in the Chicago loop where you first learn the real meaning of "crowds." Within this compact area, roughly five blocks by seven, bounded by the elevated structure, more than one million people jam pack daily. State and Madison Streets, in the heart of the loop, are said to be the busiest intersection in the world.

Chicago's outstanding list of spectator sports constitutes one of the city's major attractions.

### Baseball Seats Reserved

If you are a sports fan you can root for the Cubs and the Sox of professional baseball. A block of 300 seats has been reserved for Friday, Sept. 12, White Sox vs. Yankees night game.

"This could be the White Sox year."

So spoke Manager Paul Richards during his last visit to Chicago prior to the opening of the spring training.

"In my book none of the other clubs in the American League is superior to the White Sox," continued the tall Texan. In order that the White Sox finish on top we need comparable performances from our outstanding players of last season, plus help from players acquired via trades and purchases during the off season. . . ."

Do you like horse racing? You can bet win, place or show at five beautiful tracks which provide continuous racing until November.

Do you like girls and glitter? The Chez Paree and the Edgewater Beach Walk are famous for these.

Shopping in Chicago's mammoth department stores and exclusive salons is a popular pastime for many visitors. A package bearing a homecoming gift from Field's, Carson's, Mandel's, Stevens, Martha Weathered, Bonwit Teller's, or Saks Fifth Avenue, to mention just a few of the many fine places to shop, always receive a special welcome.

Chicago's museums, Art Institute, Planetarium, Aquarium, opera, symphony orchestra, lake cruises, social settlements, and zoos—each one has a special appeal. The Buckingham Memorial Fountain in Grant Park recently performed for its twenty-three millionth visitor. The Union Stock Yards are an outstanding attraction. So, too, are the Chicago Board of Trade, the huge mail-order houses, and the numerous radio broadcasting studios.

Chicago's great universities are popular with many visitors, as are the numerous cathedrals and other places of worship, including the Bahai Temple on the city's North Shore.

You can tour the world in Chicago without ever stepping outside its boundary lines. This is because practically every foreign race is represented in the city's cosmopolitan population, and because many races have formed their own communities in which old-world characteristics have been preserved.

Chicago has more people of Polish ancestry than has Warsaw, Poland; more people of Swedish origin than Stockholm. Excellent restaurants featuring foreign food and entertainment are to be found everywhere: Little Bohemia at 26th and Halsted; Little Italy at Taylor and Halsted; Little Russia at Milwaukee and Western; Chinatown, and the Ghetto, are but a few of the many places filled with old-world charm. Grant Park on Chicago's marvelous lake front is the city's front yard. Here you may stand and view, as at a movie, the swift flow of city life as it surges down

(Continued on page 23)

# simpler

*The Wiggins Gasholder has a remarkably simple design. It has none of the complicated mechanisms of old-type gasholders. No materials that can be harmed by weather.*

# simplest

*Wiggins is the ONLY gasholder that uses no water, no tar, no grease. Wiggins assures no weather worries, no operating costs, no maintenance problems.*

# simplicity

*Wiggins is the only gasholder with an absolutely dry, frictionless seal—gas-tight and impermeable.*

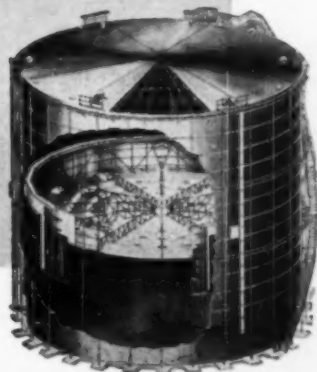
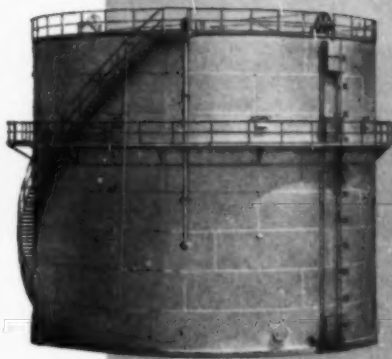
## Wiggins Gasholder

**BY GENERAL AMERICAN**



**GENERAL AMERICAN  
TRANSPORTATION CORPORATION**  
135 South La Salle Street  
Chicago 90, Illinois  
**OFFICES IN PRINCIPAL CITIES**

write for new bulletin WG-22



## DU PONT FOUNDING MARKED



**THEN** ◀ This building, used as a laboratory at the Repauno dynamite plant, Gibbstown, N. J., was forerunner of Du Pont Co.'s first formal research unit, the Eastern Laboratory, established in 1902 at Gibbstown. This picture was taken in 1897.



**NOW** ▲ The recently completed \$30,000,000 Du Pont's Experimental Station. One of the largest research laboratories in American industry, it houses nearly half of the company's research personnel.

During the expansion, nine new laboratory buildings and eleven new service buildings were erected. In addition, two buildings were substantially enlarged and a clubhouse for employees was made into a cafeteria. Most of the new construction was in the open area near the top of the picture. The older section of the Station borders historic Brandywine Creek where the company started its business in 1802.



The transformation of Du Pont Co. from maker of explosives principally, to manufacturer of chemical products took place during the successive presidencies of three du Pont brothers shown standing beneath a picture of their father, Lamont du Pont. Pierre Samuel (center) the eldest, acting president from 1909 to 1913 and president from 1915 to 1919, started the transformation by fostering pioneering scientific research within the company. Irene (left) was president from 1919 to 1926 when du Pont scientists helped make America independent of foreign sources for such commodities as nitrogen fertilizers, dyes, and many other chemicals. Under the second Lamont,\* the eighth du Pont to head the firm, expenditures for research were increased almost sevenfold.

\* He died July 24. His illness kept him from the dedication ceremonies.

**E. I. DU PONT DE NEMOURS & Co., Inc.**, celebrated the 150th anniversary of its founding, July 18, in ceremonies at the site of the company's first mill on Brandywine Creek in Wilmington. A marker, formed by one of two huge mill stones ordered from France by the founder, Eleuthere Irenee du Pont, was dedicated by Walter S. Carpenter, Jr., chairman of the board. The stone which weighs about seven tons was used by the early Du Pont mills to grind the ingredients of black powder.

An audience of nearly 7,000 was at the dedication ceremonies. The program included a historical production portraying the founding of the company, plus talks by Henry B. du Pont, great, great grandson of the founder, and vice-president of the company, Crawford H. Greenwalt president, and Walter S. Carpenter, Jr. The huge Du Pont dynasty of today springs from a young French emigrant, and student of Lavoisier, who immigrated to America to build a mill for the production of black powder, urgently needed by the new and young United States for hunting, land-clearing, and protection. Today the company has grown to where it is the largest producer of diversified chemicals, and chemical products. The first diversity in production came in 1832 when from making black powder only the company branched out into making refined saltpeter, charcoal, an acid made from wood, and creosote. Today Du Pont produces some 1,200 chemical products, and product lines.

A similar growth situation is shown in the Du Pont research facilities. Originally all Du Pont research was done in plant laboratories or in the homes of the du Pont family. In 1902 the company built the first eastern laboratory in Gibbstown, New Jersey. Last year the company dedicated a \$30,000,000 experimental station, one of the largest research laboratories in American industry.

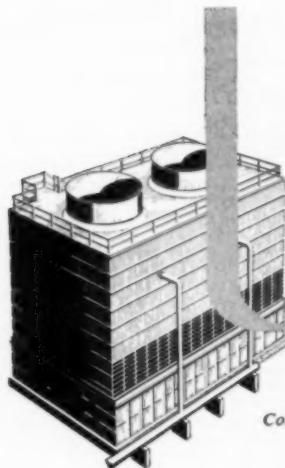
The company's operating investment is today about one and one-half billion dollars and represents a capital expenditure of about \$18,000 for each employee; 5,000 of the company's employees, staff thirty-eight research and development laboratories, and in 1951 the company spent \$47,000,000 on research.

In his talk, Crawford H. Greenwalt, president of the company, said that the "vast unexplored area of science" opened by advancing technology is a

(Continued on page 26)

# ONLY FLUOR

*induced draft counterflow  
cooling towers  
provide these  
6 exclusive features...*



## *Spiral Bevel Gear Speed Reducers*

Only Fluor-Western speed reducers incorporate curved tooth spiral bevel gears as standard design. This proven principle provides quieter, smoother, more efficient operation under the rugged conditions of cooling tower service. Other special design features include: oil-bath lubrication; dry air breather; chrome-plated shaft at oil seals; and, low-speed fan shaft mounted on special steep angle thrust and radial bearings to take combined gear thrust, fan thrust, and weight of fan assembly.

## *Unique Fan Blade Design*

The Fluor Type HC Stainless Steel Fan blades, furnished as standard on every Fluor Counterflow Cooling Tower, are a joint development of The Fluor Corporation and Solar Aircraft Company. Designed specifically for induced draft cooling tower service, their unique air foil handles maximum air volumes at minimum tip speeds and horsepower requirements. Design plus mechanical arrangement eliminates recirculation of air and resulting power-consuming turbulence.

## *Internal Gusset Plate Construction*

Fluor Counterflow Cooling Towers alone make full use of tensile as well as compressive strength of structural members! Their internal gusset plate design duplicates that used in wooden bridge construction. These simple, yet extremely strong joint connectors mean longer tower life, lower total tower weight, fewer and simpler castings, greater ease of erection, and minimum spoilage should the structure be dismantled, moved and re-erected.

## *Patented Vibration Cut-Out Switch*

The Vibration Cut-Out Switch developed and patented by Fluor in 1944 protects tower structure and mechanical equipment by stopping the motor should excessive vibration suddenly occur. In addition to its value as an emergency safety device, the switch can be utilized by the operator as a positive "on-off" switch during routine inspection of tower structure and mechanical equipment. The motor cannot be started accidentally once the switch is placed in the "off" position.

## *Sloping-Bar Grid Decking*

Exclusive Fluor-designed sloping-bar grid decks are of rough-finished 1" select redwood machine-nailed to 1" x 2" cleats—strong enough for use as scaffolding during erection, rugged enough to withstand the erosion of falling water. This means low maintenance and replacement cost. The sloping-bar design and arrangement of each deck cross member combines the advantages of maximum deck surface with minimum air pressure drop through tower.

## *Complete Prefabrication of Structure*

Only Fluor Counterflow Cooling Towers are completely prefabricated. This offers many advantages to the operator. Tower parts are "packaged" for rapid delivery, marked for orderly erection. Erection is faster, easier, at lower cost. All cutting, drilling and nailing is completed at the factory. Prefabrication means standardization—low-cost replacement of standard parts that may become damaged over the years. It means uniformity in both performance and appearance.

Contact your nearest Fluor representative for detailed information. You Can Be Sure With Fluor

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# CENTENNIAL SYMPOSIUM

## PALMER HOUSE

Thursday, Sept. 11, 1952

Morning Session beginning  
at 9:15 A.M.

Session No. 1

Red Lacquer Room

### Co-Chairmen

Harry McCormack, editor  
Putman Publishing Co.  
Chicago

P. D. V. Manning, vice-president  
International Minerals and Chemical  
Corp., Chicago

The Fluidized Solids Technique in  
the Petroleum Industry.—R. C.  
Gunniss, assistant general manager,  
manufacturing, Standard Oil Com-  
pany (Indiana), Chicago

Applications of Low-Temperature  
Carbonization.—R. E. Zinn, de-  
partment of chemical engineering,  
Northwestern University, Evanston,  
Ill.

Industrial Carbon.—B. W. Gamson,  
director, research and development,  
Great Lakes Carbon Co., Morton  
Grove, Ill.

Chemical Engineers in the Packing  
Industry.—V. Conquest, vice-presi-  
dent, Armour & Co., Chicago

Afternoon Session beginning  
at 1:30 P.M.

Session No. 2

Red Lacquer Room

### Co-Chairmen

W. E. Brinker, assistant chief engineer,  
Corn Products Refining Co.  
Chicago

L. F. Stutzman, chairman,  
department of chemical engineering  
Northwestern University  
Evanston

Mixing: Present Theory and Prac-  
tice.—J. H. Rushton, director, depar-  
tment of chemical engineering, Illinois  
Institute of Technology, Chicago

Particle Sizing With Special Refer-  
ence to Phosphate Concentration  
Operations.—I. Milton Le Baron, di-  
rector of laboratories, research divi-  
sion, International Minerals and  
Chemical Corp., Chicago

The Art of Material Handling Equip-  
ment.—E. A. Wendell, sales manager,  
Caldwell Plant, Link Belt Co., Chi-  
cago

Recovery of Sulfur Dioxide from  
Waste Gases.—H. F. Johnstone,  
chairman, department of chemical en-  
gineering, University of Illinois, Ur-  
bana, Ill., and William E. West, Jr.,  
chemical engineering department, Uni-  
versity of Illinois, Urbana

# TECHNICAL SESSIONS

Friday, Sept. 12, 1952

Morning Session beginning  
at 9:30 A.M.

Session No. 3

Red Lacquer Room

## General Technical Program

### Chairman

O. A. Hougen, chairman,  
department of chemical engineering  
University of Wisconsin  
Madison, Wis.

Stream Self-Purification—Analysis,  
Sampling, and Forecasting.—C. S.  
Veltz, chairman, department of public  
health statistics, University of Michi-  
gan, Ann Arbor, Mich.

Fluidization of Solid Particles in  
Liquids.—E. W. Lewis and E. W.  
Bowerman, technical and research di-  
visions, Humble Oil and Refining Co.,  
Baytown, Tex.

A New Application of Fluidization.—  
R. B. Thompson, assistant manager,  
Fluo-Solids Sales, The Dorr Co.,  
Stamford, Conn.

Heat Transfer in Fluidized Bed  
Region of Gas-Solid Systems.—  
W. T. Brazelton, department of chemi-  
cal engineering, Northwestern Uni-  
versity, Evanston

Mean Temperature Differences in  
Cross Flow Exchangers.—B. W.  
Gamson, director, W. Mink, research  
and development department, Great  
Lakes Carbon Co., Morton Grove

Morning Session beginning  
at 9:15 A.M.

Session No. 4

Grand Ball Room

## Symposium—Mixed Bed Ion Exchange

### Chairman

F. J. Van Antwerpen, editor  
Chemical Engineering Progress  
New York, New York

Theory of Monobed Ion Exchange.—  
Joseph Thompson, The resinous prod-  
ucts division, Rohm and Haas Co.,  
Philadelphia, Pa.

Design of Mixed Bed Ion Exchange  
Units.—John F. Wants, Illinois  
Water Treatment Co., Rockford, Ill.

Engineering Results and Experiences  
with Mon-O-Tank Ion Exchange  
Units.—S. F. Alling, vice-president,  
Hungerford & Terry, Inc., Clayton,  
N. J.

Mixed Bed Demineralizing of High  
Pressure Boiler Feedwater.—M. E.  
Gilwood, director of research, The  
Permutit Co., New York, New York

### Panel and Audience Discussion.

Applications.—E. W. Scarritt, Elgin  
Softener Co., Elgin, Ill.

Domestic Possibilities.—R. Schulze,  
research director, Culligan Zeolite  
Co., Northbrook, Ill.

Questions from the audience will be  
answered by all members of the  
Symposium and Panel.

Friday, Sept. 12, 1952

Afternoon Session beginning  
at 2 P.M.

Session No. 5

Red Lacquer Room

## General Technical Program

### Chairman

C. G. Kirkbride, president,  
Houdry Process Corp.  
Philadelphia

Factors Influencing the Properties of  
Spray-Dried Material.—J. A. Duffie,  
Office of Naval Research, Chicago.  
W. R. Marshall, department of chemi-  
cal engineering, University of Wis-  
consin, Madison, Wis.

Development and Performance of  
General American-Type H Rotary  
Dryer.—G. Gutzeit, director, J. R.  
Spraul, assistant to director, research  
and testing laboratories, General  
American Transportation Corp., East  
Chicago, Ind.

Manufacture of Fatty Acids and Fat  
Chemicals.—R. H. Potts, technical  
adviser, Armour chemical division,  
Armour & Co., McCook, Ill.

Graphical Interpretation in Ternary  
Distillation.—Karl Kammermeyer,  
chairman, department of chemical en-  
gineering, State University of Iowa,  
Iowa City, Iowa. K. T. Lee, Chemi-  
cal Construction Co., New York,  
New York

Plate Efficiencies of an Extractive  
Distillation Column.—Karl Kam-  
mermeyer and Dr. K. T. Lee (as  
above)



**Saturday, Sept. 13, 1952**  
**Morning Session beginning**  
**at 9:30 A.M.**

Session No. 6

**Dining Room No. 14**

**Symposium—Distribution of Chemicals**

**Co-Chairmen**

Henry Dahlberg, Jr., supervisor technical economics, research division, International Minerals and Chemical Corp., Skokie, Ill.

R. M. Lawrence—general development department Monsanto Chemical Co. St. Louis, Mo.

**Transportation in the Chemical Industry.**—E. J. Landis, general traffic manager, International Minerals and Chemical Corp., Chicago

**The Packaging and Marking of Chemicals.**—Don Ballman, general sales manager, Dow Chemical Co., Midland, Mich.

**Ingenuity and Ideas.**—Neill Gilliatt, account executive, McCann-Erickson, Inc., Chicago

**Some Principles of Selecting Economic Sales Channels.**—Hoyt Corley, manager, new products department, Armour & Co., Chicago

**Morning Session beginning**  
**at 9:30 A.M.**

Session No. 7

**Red Lacquer Room**

**General Technical Program**

**Chairman**

K. H. Hachmuth  
research planning board  
Phillips Petroleum Co.  
Bartlesville, Okla.

**Critical Temperatures and Pressures of Hydrocarbons.**—George Thodos, department of chemical engineering, Northwestern University, Evanston, Ill., and G. V. Michael, chemical engineer, Armour & Co., Chicago

**Thermodynamic Properties of Hydrocarbon Mixtures.**—W. C. Edmister, California Research Corp., Richmond, Calif., and L. N. Canar, department of chemical engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

**Interfacial Area in Liquid-Liquid Agitation.**—Theodore Vermeulen, chairman, department of chemical engineering, University of California, Berkeley, Calif., and Gordon E. Langlois, research chemist, California Research Corp., Richmond, Calif.

**Calculation of Leaching Operations—Equilibrium and Non-Equilibrium Conditions.**—Edward G. Scheibel, head, chemical engineering group, Hoffmann-La Roche, Inc., Nutley, N. J.

**The Effect of Packing Size and Column Diameter on Mass Transfer in Liquid-Liquid Extraction.**—Robert B. Beckmann, department of chemical engineering, Carnegie Institute of Technology, Pittsburgh, Pa., and Irving Leibson, chemical engineer, Humble Oil and Refining Co., Baytown, Tex.

**CHICAGO MEETING**

(Continued from page 18)

Michigan Avenue. The impression you get is one of power, of confidence, of organized effort. The Michigan Avenue skyline is one of the world's most impressive. Behind that skyline are cities within cities, each functioning with machine-like precision . . . and in the aggregate forming Chicago, one of the marvels of the world.

It would take a good part of a lifetime to see it all. Complete information concerning items of interest and entertainment may be obtained by sending a stamped (6 cent) self-addressed envelope with your request to The Visitors Bureau of the Chicago Association of Commerce and Industry, One North LaSalle Street, Chicago 2, Ill.

**CENTENNIAL PROGRAM**

The centennial program itself will begin Wednesday, Sept. 3, at the Eighth Street Theatre, with an opening sym-

posium covering the role of the organized profession. A symposia on various engineering subjects will be held every day, thereafter.

Wednesday, Sept. 10, will be known as "Engineers Day," and a special program is being developed which will include a luncheon, award ceremonies, and a reception and banquet in the evening.

A special pageant entitled, "Adam to Atom," began running in Chicago July 12, and will continue during the engineers' meeting until Sept. 15. The play depicts the development of engineering principles, and the engineering profession from prehistoric times down to the development of atomic energy. Location will be the theatre in the Museum of Science and Industry, 57th Street and Lakeshore Drive.

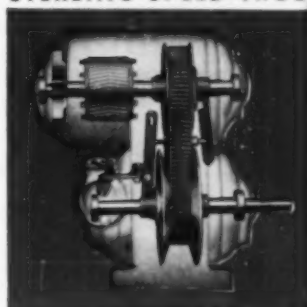
Technical exhibits will be shown in the Museum of Science and Industry

(Continued on page 64)

## How One Speed-Trol Leads to Another

Mr. J. H. Kirby, Vice President of The Humko Co., writes: In processing vegetable oil and shortening we must drive our batch mixers at various speeds . . . a Speed-Trol was installed for this purpose . . . we were so well pleased with its performance that we installed Speed-Trols on ALL of our vegetable oil batch mixers . . . Speed-Trols give the exact speed regulation needed for vegetable oil processing.

### STERLING SPEED-TROL



### OUTSTANDING FEATURES:

Infinite speeds—positive speed regulation—fingertip control—large indicator—positive pulleys—no springs—belt tension in proportion to load—protected—streamlined—Herringbone Rotor—through ventilation—versatile mounting—NEMA dimensions—shock absorbing—quiet operation—rugged—compact—dependable—long life.

70 ILLUSTRATIONS showing how Sterling Electric Power Drives reduce production costs. Write for Bulletin No. B-120.

## STERLING

ELECTRIC MOTORS

Plants: New York City 51; Van Wert, Ohio;  
Los Angeles 22; Hamilton, Canada; Santiago, Chile  
Offices and distributors in all principal cities

# Now, from Honeywell... *a flow*



Wherever supervision of your plant processes requires flow measurement, Honeywell has the right instrumentation for the job.

Included are instruments specifically designed for accurate metering and flow cost-accounting of process fluids, with either linear or square root scales and continuous integration... with a choice of electric or pneumatic transmission from the metering point.

Flow-measuring systems, including proper control, are patterned to your exact requirements

... offer you the advantages of Honeywell's single responsibility from sensing element to control valve. Each part of the system is designed and built with the needs of process designers, production engineers and instrument men foremost in mind.

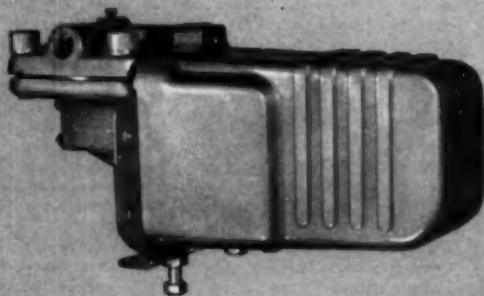
Call in our local engineering representative for a discussion of your application... he is as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO.,  
Industrial Division, 4427 Wayne Ave., Philadelphia 44, Penna.

## BROWN DIFFERENTIAL CONVERTER

This new flow transmitter, based on the pneumatic balance principle, is setting high standards of precision and simplicity in field operation. Using no mercury, seals or strainers, it converts the pressure differential at the metering orifice into a proportionate air output pressure which is a measure of flow. Response is rapid and accurate. Range is continuously adjustable from 20 to 200 inches of water, and is easily changed in the field without special tools or extra parts. Applicable to either liquids or gases, the Differential Converter is easily installed, cleaned and calibrated in the field.

For graphic panels and other applications requiring compact instrumentation, the Differential Converter is part of a new Honeywell flow control family which includes Tel-O-Set Indicators, Recorders and Controllers. Write for "Centralized Instrumentation—Unlimited," a new brochure describing types of Brown panelboards and instrument components available for industry.



● Important Reference Data... Write for Catalog No. 2281 on the Differential Converter...

*meter for every requirement*



### **BROWN EVENLY GRADUATED FLOW METER**



Costs for distribution and utilization of fluids can be accurately determined with this meter . . . available as a mechanical meter (with integral meter body) or as an electric meter (with electric transmission from remotely located meter body).

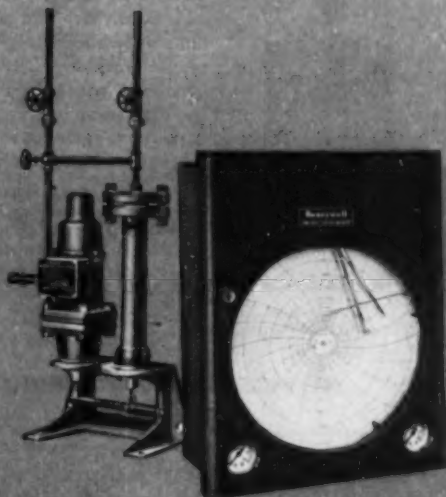
Features linear scale and electronic integration for simplified flow accounting. Electronic integrator is simple, accurate and easily accessible for calibration and inspection. Characterized corrosion-resistant bell automatically provides straight-line flow measurement.

### **BROWN SQUARE ROOT FLOW METER**

This instrument's expanded, square-root scale affords extra sensitivity for automatic flow control applications. Available with on-off, throttling or Air-O-Line (proportional plus automatic reset) pneumatic control . . . Supplied for use with electric or mechanical meter bodies, in a wide choice of types: low pressure, intermediate pressure and all-purpose—plus sealed armature and area types for special fluids. Interchangeable range tubes afford broad flexibility in the field.

MINNEAPOLIS  
**Honeywell**  
BROWN INSTRUMENTS

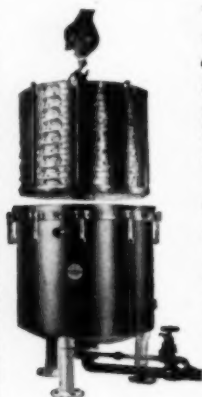
*First in Controls*



SPARKLER FILTERS·SPARKLER FILTERS

# SPARKLER FILTERS

Designed to use diatomaceous earth without the necessity of a fibrous material pre-coat to hold cake on the plate.



With Sparkler horizontal plates there is no tensile strain on the cake. Even a very thin cake can be built up without danger of slipping or breaking as it rests in a horizontal position on the plate and requires no pressure to hold it in position. This saves considerable cost in pre-coating.

Sparkler horizontal filter plates can be removed for cleaning in one unit assembly and a clean set lowered into the filter tank immediately. This feature reduces down time to a matter of minutes.

Representatives in all principal cities in the U.S.A.

**SPARKLER MANUFACTURING CO.**  
Mundelein, Ill.

Sparkler International Ltd.  
Herengracht 568, Amsterdam, Holland

Sparkler Western Hemisphere Corp.  
Mundelein, Ill., U. S. A.

## DU PONT

(Continued from page 20)

"new continent" fully as rich and abundant as the geographical America of 150 years ago, and "as full of promise for the future."

Mr. Greenwalt said that Eleuthere Irenee du Pont came to the United States from France to find freedom, and that here he had been free to build his enterprise on his own initiative, free "to undertake the risks, carry the burdens, and reap the rewards."

"Yet today," Mr. Greenwalt said, "freedom has been mortgaged—bit by bit—on the plea of crisis or emergency. Rights of minorities in the economic area have been disregarded, to the point where the virtues of thrift, enterprise, and initiative have lost much of their original glamour." Mr. Greenwalt continued as follows:

Our progress up to now has been in direct ratio to the degree of human freedom afforded us. Our rate of progress in the future will be determined in identical fashion. I am quite confident that this essential truth will be recognized and affirmed by the American people. With freedom assured, there can be no limit to the progress we can make. The new continent we have before us has no boundaries. Its horizons are as broad and as limitless as the spirit and the imagination. For us it is the opportunity of multiplying our national inheritance many times. I am sure we can do so.

## NATIONAL LEAD BUYS GERMAN FIRM

National Lead Co. announced last month that Titangesellschaft m.b.H. of Leverkusen, Germany, in which National Lead has had a fifty per cent interest, has been wholly acquired through purchase of the remaining capital stock from I. G. Farbenindustrie. Joseph A. Martino, president of National Lead Co., stated that the transaction was approved by the Allied Control Council. Titangesellschaft operates a plant in the British Zone in Leverkusen, Germany, producing titanium dioxide pigments for European consumption. The plant is the largest of its type in Europe.

Ilmenite ore for the plant, which is expected to have an output of pigment adequate to supply all the requirements of Western Europe, will come from National Lead Co.'s mine and plant in Norway. Steam, power, water, sulfuric acid and raw materials other than ilmenite, will be furnished under contract by Farbenfabriken Bayer.

Titangesellschaft m.b.H., owned jointly by Titan Co. A/S and I. G. Farbenindustrie, was formed in 1927, and the plant was constructed in 1928. The British Military Government has supervised both the administration and operations of the plant since the end of World War II.

## HIGH PRESSURE SYMPOSIUM

A symposium on high pressures is being held by the Industrial Instruments and Regulators Division of the A.S.M.E. in connection with the annual conference and exhibit of the Instrument Society of America, to be held in the Cleveland Auditorium, Cleveland, Ohio, Sept. 9 and 10. The symposium which is under the direction of W. H. Howe, chief engineer, The Foxboro Co., will feature fifteen papers spread over the two days. A luncheon will also be held on Tuesday, at which W. G. Brombacher, chief of the Mechanical Instruments Section, National Bureau of Standards, will be toastmaster, and Dr. Elmer Hutchinson, acting president of the Case Institute of Technology, will speak on "Preparation for a Career In Industry."

The technical program is as follows:

**Introduction to the Symposium on Measurement of High Pressures**—Percy W. Bridgman, professor of mathematics and natural philosophy, Research Laboratory of Physics, Harvard University.

**The Piston Gage as a Precise Pressure Measuring Instrument**—Dr. Daniel Johnson, National Bureau of Standards and Donald H. Hewhall, Harwood Engineering Inc.

**A High Pressure Wire Gage Using Gold-Chrome Wire**—Horace Darling, research engineer, The Foxboro Co.

**An Application of High Pressure in Geophysics: Experimental Rock Deformation**—John Handin, Shell Oil Co. (Exploration and Production Research Laboratory)

**Techniques and Equipment for the Generation of Dynamic High Pressures**—E. J. Mieczewicz, materials engineer; chief, Experimental Stress Analysis Unit, U. S. Naval Ordnance Laboratory.

**A High-Speed High-Pressure Gage**—P. L. Edwards, U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md.

**Design of High-Pressure Pumps**—R. W. Hiteshue, U. S. Department of the Interior, Bureau of Mines

**A Sensitive Pressure Controller for High Pressure Service**—P. L. Golden and A. F. Headrick, U. S. Department of the Interior, Bureau of Mines

**High Pressure Developments at Yale University**—Barnett F. Dodge, professor of chemical engineering, Sterling Chemistry Laboratory, Yale University

**Influence of Residual Stress on Behavior of Thick-Wall Closed-End Cylinders**—J. H. Faupel and A. R. Furbeck, Du Pont Co., Inc.

**Rupture Disc Design Evaluation and Bursting Tests**—G. R. Prescott, Du Pont Co., Inc.

**Panel Discussion—Safety Precautions in High Pressure Operation.**

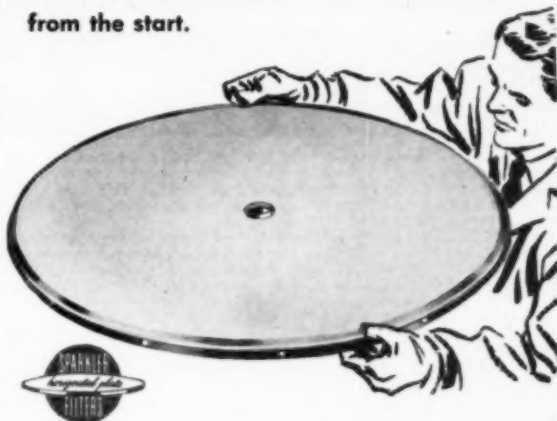
**Gaskets for High Pressure Vessels**—Andrew R. Freeman, American Instrument Co., Inc.

(Continued on page 62)

SPARKLER FILTERS·SPARKLER FILTERS

# SPARKLER FILTERS

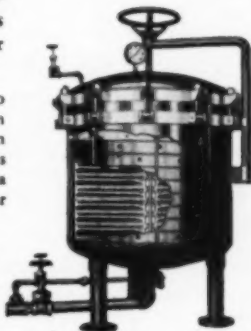
Designed for maximum pre-coat economy. Only a thin pre-coat cake is necessary to assure brilliant clarity of the filtrate right from the start.



Sparkler horizontal plates permit the filter media to be floated onto the plate and deposited with gravity into a cake of uniform thickness and uniform density even though the first pre-coat is very thin. This saves considerable time and Filter Aid in pre-coating.

Since no pressure is needed to hold this thin pre-coat cake in position it is possible to begin filtering operation with less pressure which results in a cake of less density and greater flow rate.

For personal service on your filtering problems, address correspondence to Mr. Eric Anderson



**SPARKLER MANUFACTURING CO.**  
Mundelein, Ill.

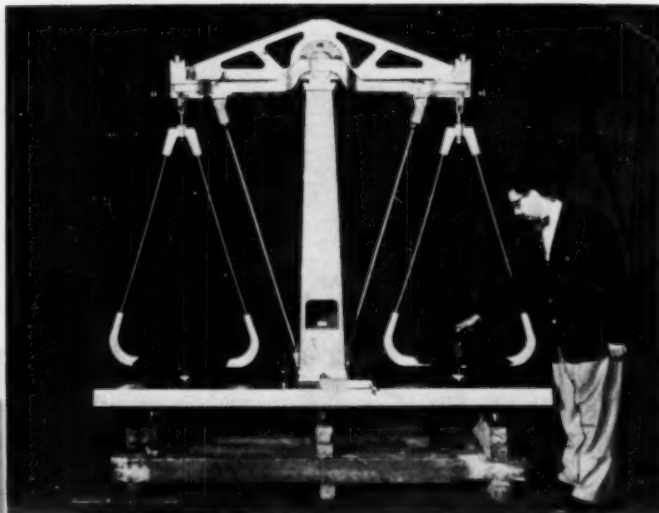
Sparkler International Ltd.  
Herengracht 568, Amsterdam, Holland

Sparkler Western Hemisphere Corp.  
Mundelein, Ill., U. S. A.

SPARKLER FILTERS·SPARKLER FILTERS



## VOLAND COMPLETES LARGEST BALANCE



One of the largest balances ever built has just been completed by Voland and Sons, New Rochelle, N. Y. This huge instrument, one of a few of this size and sensitivity in the world, has an over-all weight of 3500 lb. This type of balance is usually used for weighing bullion and precious metals, where large capacity with extreme accuracy is required.

The capacity of this balance is one thousand times as great as that of conventional 200 g. balances. Yet it has the same sensitivity and accuracy. With a total capacity of 200 kg. in each pan, it maintains a sensitivity of better than 100 mg. A piece of metal, 35/10,000 of an ounce, will move the mechanism even when it is loaded to full capacity of 400 lb.

The balance measures 8 ft. high and rests on a base 9 ft. long.

Although the pans are large enough to seat comfortably a grown man, it is impossible to weigh the man because the needle cannot be kept at zero long enough—the balance records human evaporation of perspiration while it is going on.

## N.S.F. COMPILES FEDERAL RESEARCH INFORMATION

Federal agencies supporting scientific research and development programs by grant or contract with educational and other nonprofit institutions have been asked to supply the National Science Foundation with statistical and fiscal information about their programs for fiscal 1951 and 1952. The Foundation is compiling such information on a continuing basis at the request of the Bureau of the Budget, which has gathered similar information on Federal research and development programs in previous years. The final report, it is hoped, will be available before Jan. 1, 1953.

The information will be compiled under various functional classifications, including basic research, applied research, development, and increase of research and development plant, and subject classifications including biological, medical, agricultural, physical, mathematical, engineering, and social sciences. In addition the information will be grouped by states and institutions.

Typical examples of non-profit institutions for which information will be gathered are colleges and universities, research institutes, research founda-

tions, experiment stations, hospitals, libraries, museums, observatories, and corporations organized specifically to do scientific research and development for the Federal Government on a non-profit basis. Information on direct research activities of agencies of the Federal Government will be excluded, but the report will include information on Federal support to agencies of state, local or foreign governments.

## ALGONQUIN CHEMICAL TO NATIONAL DISTILLERS

National Distillers Products Corp. announced recently that it is acquiring the business and assets of the Algonquin Chemical Co., manufacturers of chlorine, caustic soda and sulfuric acid, with plants located at Huntsville, Ala.; Dubuque, Iowa; and Lawrence, Kan. No change in the operation or personnel at the plants is contemplated as a result of the acquisition.

National Distillers Products Corp. also announced that it has completed arrangements for the sale of its White Rock division to a group of private investors who will continue the existing business of the White Rock Co.

## KODAK OFFERS 14 FELLOWSHIPS

To encourage training in chemical research and to assist promising young scientists, thirteen U. S. educational institutions have been offered fourteen fellowships by Eastman Kodak Co. for 1952-53. All for advanced study, nine of the fellowships are in chemistry, two in chemical engineering, and three in physics.

Tennessee Eastman Co., a division of Kodak at Kingsport, Tenn., has offered five additional fellowships to five educational institutions in the southeastern states. Three of these are in chemistry, two in chemical engineering.

Each award provides \$1,400 plus an allowance for tuition and fees.

The fellowships are awarded to the colleges. They select a research student in the last year of study for his doctorate. The basis of selection is the student's demonstrated ability in his major field of study, a high degree of technical promise, soundness of character and personal traits, and financial need.

Kodak established the fellowships in 1939. The 1952-53 fellowships will be awarded to Catholic University of America, Illinois Institute of Technology, University of Illinois, Massachusetts Institute of Technology, Northwestern University, Ohio State University, Princeton University, University of Rochester, Stanford University, University of Texas, Cornell University, Harvard University, and University of Wisconsin.

The fellowships from Tennessee Eastman Co. will be awarded to University of Tennessee, Emory University, University of North Carolina, Virginia Polytechnic Institute, and Georgia School of Technology.

## NAVY WANTS ENGINEERS

Several vacancies at the present time exist in the engineering department of the U. S. Naval Air Rocket Test Station. Some of these are described as follows:

Chemical engineer (GS-12) at a salary of \$7040 per annum as head of the special projects branch, propellants division. He directs specialized investigations into the problems of combustion of solid and liquid propellants in rocket engines, determines physical and thermodynamic properties of propellants, studies of corrosion of materials by propellants.

Chemical engineer (GS-9) at an annual salary of \$5060 to serve as project engineer in the special projects branch, propellant division. In addition to specialized investigations as mentioned above, he studies materials for storage and handling of propellants and prepares reports.

Applicants should complete standard Form No. 57, Application for Federal (Continued on page 30)

since 1926...

*Nothing takes the place  
of Glycerine*

For more than 25 years the Norwich Pharmacal Company has used U. S. P. Glycerine in the Zemacol formulation. This year 'round seller helps to relieve the itching and burning of a wide variety of skin irritations — from eczema-like rashes to poison ivy. Promoted as the "invisible bandage", Zemacol has long been one of Norwich's "top ten" products.

#### FULLY ACCEPTED... FULLY AVAILABLE IN ALL GRADES!

U. S. P. Glycerine demonstrates its versatility once again in dermatological preparations... where it often performs a *triple* function as humectant, emollient and solvent.

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That's why manufacturers in the pharmaceutical field look to Glycerine's unique range of properties. Further, users of any volume can count on a firm source of supply. Glycerine has become a component of *one out of four* prescriptions... an ingredient in hundreds of proprietary remedies. Why? We review the reasons in a booklet titled "Why Glycerine for Drugs and Cosmetics?" A copy is yours for the asking.

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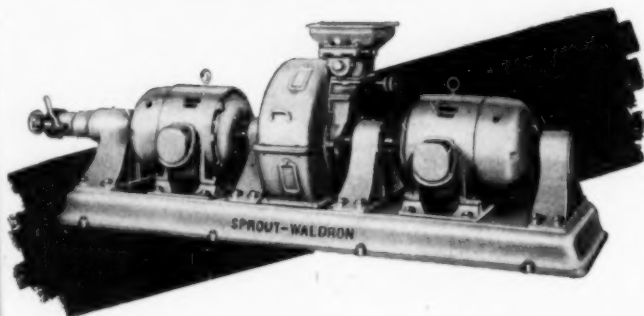
## GRINDER

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**\*for CUTTING**

**\*for CRUSHING**

**\*for TEARING**



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If you have a size reduction problem, Sprout-Waldron is uniquely well-equipped to help you. Why not take advantage of our experience based on hundreds of successful installations in the chemical processing and allied fields? Write for full details to Sprout-Waldron & Co., Inc., 17 Logan Street, Muncy, Pennsylvania.



**SPROUT-WALDRON**

*The Best in PROCESSING EQUIPMENT Since 1866*

### NAVY WANTS ENGINEERS

(Continued from page 28)

Employment, which is available at any post office, and forward to the Industrial Relations Officer, Industrial Relations Department, U. S. Naval Air Rocket Test Station, Lake Denmark, Dover, N. J.

### RESEARCH PLANNED ON PLATE EFFICIENCIES

A five-year research program on plate efficiencies in fractionating towers, a co-operative project between the American Institute of Chemical Engineers and twenty-five chemical, petroleum and engineering companies, recently got under way according to an announcement from the Research Committee of A.I.Ch.E. The program supported by \$64,000 in contributions from the companies for the first year, will be carried out at the University of Michigan, University of Delaware and the Polytechnic Institute of Brooklyn.

The research projects will cover a basic investigation of the fundamentals of tray efficiency both in fractionation and absorption. As the program is now set up the initial work will cover the effect of system properties on tray efficiencies. Later work will include tray design and column hydraulics.

The Research Committee of the A.I.Ch.E. was set up by the Council of the Institute in July, 1950, "to foster research projects in chemical engineering which by their scope, complexity, or general nature, were such that no single institution or company could afford to institute a comprehensive planned research program."

The work on the initial project will be under the supervision of Dr. Brymer Williams at the University of Michigan; Dr. J. A. Gerster at the University of Delaware; and Dr. Ju Chin Chu at Polytechnic Institute of Brooklyn.

Companies contributing are:

Columbia-Southern Chemical Corp.; Newport Industries, Inc.; The Barrett Division, Allied Chemical & Dye Corp.; Standard Oil Development Co.; Standard Oil Co. (Indiana); Sharples Chemicals, Inc.; M. W. Kellogg Co.; Gulf Research & Development Co.; Hercules Powder Co.; Union Carbide & Carbon Corp.; Sun Oil Co.; Universal Oil Products Co.; American Cyanamid Co.; Socony-Vacuum Labs.; The Lummus Co.; Tide Water Assoc. Oil Co.; The Fluor Corp., Ltd.; The Ohio Oil Co.; Hydrocarbon Research, Inc.; The Dow Chemical Co.; Monsanto Chemical Co.; Arthur D. Little, Inc.; Eastman Kodak Co.; The Pure Oil Co.; Vulcan Copper & Supply Co., and Ethyl Corp.

Members of the Institute Research Committee are: W. E. Lobo, chairman, M. W. Kellogg Co.; W. E. Catterall, Standard Oil Development Co.; R. A.

(Continued on page 40)

**ADVANCED  
CONSTRUCTION  
OF  
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EVAPORATORS  
GIVE**

Buflovak Evaporators offer the chemical industry efficient evaporation of processing, high capacity and maximum recovery of solids. All of these because of advanced scientific design in every BUFLOVAK Evaporator!

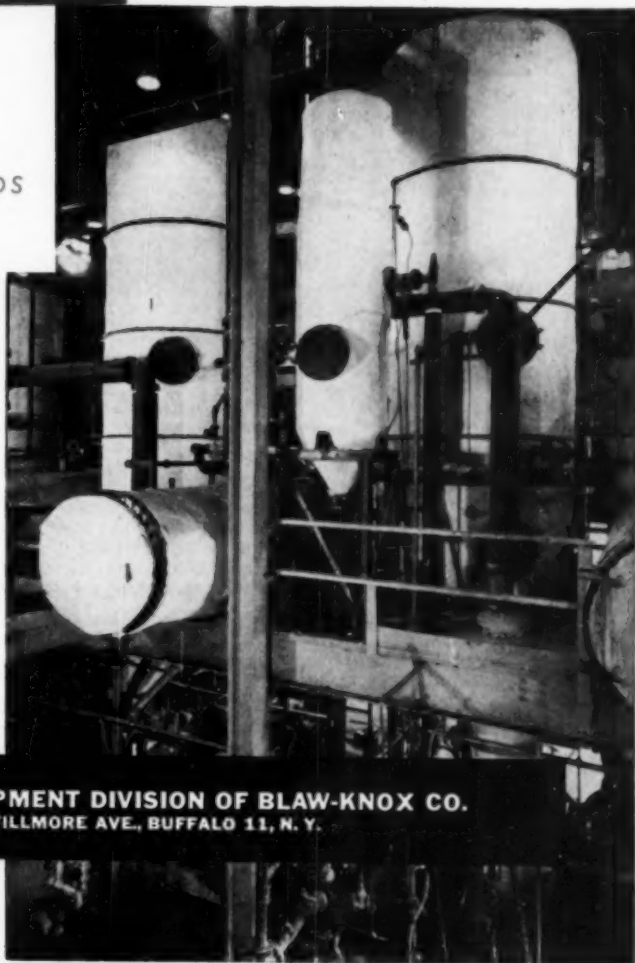
Modern design insures maximum capacity, virtually complete recovery of all solids, and low operating costs. Automatic controls maintain a high level of operating efficiency, and simplify operation . . . all with their profit-building advantages.

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## NEW RESEARCH LAB. OF INTERNAT. MINERALS

International Minerals & Chemical Corp. officially opened its new general research laboratory in Skokie, Ill., with three days of inspections beginning June 26. Louis Ware, president, and Paul D. V. Manning, vice-president in charge of research and development, served as co-hosts for the events.

Of modern, fireproof construction, the new laboratory will house a staff of scientists and technicians working on the broader research projects of the corporation, and will make it possible to centralize a large part of International's research operations. It is the outcome, Mr. Ware said, of planning that began during the early war years when it was impossible to build a research center. Enough ground has been acquired to provide for the ultimate erection of an office building adjacent to the laboratory.

According to Dr. Manning, approximately seventy-five research people will be employed by the laboratory on projects relating to the production and use of the corporation's present products and to the development of new products. International currently produces phosphate, potash, plant food, phosphates and potassium chemicals, chlorine products, amino products, bentonites, refractory specialties and bonding clays.

## SQUIBB-MATHIESON MERGER ASKED

A proposed merger of E. R. Squibb & Sons into Mathieson Chemical Corp. on the basis of converting five shares of Squibb common stock into three shares of Mathieson common stock was announced last month in a joint statement by Thomas S. Nichols, president and chairman of Mathieson, and Carleton H. Palmer, chairman of the board and Lowell P. Weicker, president of Squibb.

Special meetings of the shareholders of both companies to approve the merger, will be called in the near future.

Mathieson Chemical Corp., the surviving corporation, will operate E. R. Squibb & Sons as a separate division.

## SULFUR SHORTAGE ENDED—WILLIAMS

The world sulfur shortage, critical since the outbreak of the Korean War, has improved to the point where virtually all sulfur requirements in the United States are being met, Langbourne M. Williams, Jr., president of Freeport Sulphur Co., declared recently. Furthermore, he added, the outlook for the future is "extremely encouraging" as a result of nearly 100 new projects in the United States and other free-world countries that will substantially increase the supply of sulfur in various forms.

These projects, it is estimated, will add approximately 4,000,000 long tons of sulfur per year by the end of 1955, he said. This amount is equivalent to one third of the estimated 1951 free world production of about 12,000,000 tons of sulfur in all forms. Mr. Williams said further:

The large gap between sulfur supply and demand no longer exists. Although sulfur consumption is still under government limitation, all but a few consumers in this country are getting all the sulfur they need, and the situation abroad has also improved.

The outlook for the future is extremely encouraging. There is enough new production in sight to dispel the threat of a continuing shortage. Even if the requirements of U. S. industry and agriculture should increase by 1955 to the level estimated by D.P.A., there will be enough sulfur to meet the demand assuming the new projects measure up to expectations.

The new projects listed by the Freeport official are expected to add approximately 1,500,000 long tons of sulfur in various forms to the annual production capacity of the free world by the end of this year, 1,350,000 tons more by the end of 1953, 250,000 tons more by the end of 1954, and 900,000 tons more by the end of 1955.

The efforts to increase the supply, he

said, cover a broad range of activity. They include five Frasch process salt dome projects in Louisiana and Texas, which with an estimated annual production of 1,370,000 tons of sulfur are making the largest contribution. The bulk of the production will be under way by the end of 1953.

In addition, Mr. Williams said, there are under way fifty projects to obtain sulfur in the form of brimstone from native deposits, sour natural gas, refinery gases, etc., and thirty-seven projects to obtain sulfur in various other forms. "The American sulfur producers by 1951 had increased their production to about two and a half times the average for the prewar period 1935-39," Mr. Williams said.

## CAMBRIDGE RESEARCH FIRM EXPANDS

Arthur D. Little, Inc., Cambridge, Mass., industrial research and engineering firm, will move its mechanical division from its present location to a new and larger building in the West Cambridge industrial area. Earl P. Stevenson, president, recently announced.

Ground has been broken for a 30,000 sq. ft., two-story plant which will include all engineering offices and mechanical facilities of this division.

The mechanical division is a relatively new outgrowth of Arthur D. Little, Inc.

Allen Latham, Jr., vice-president of Arthur D. Little, Inc., and engineering director of the mechanical division, explains that the principal reason for the move is to provide more space and mechanical facilities for efficiently carrying out the increased activities of the division.

## NEW METHOD FOR ODORIZATION OF L.P.G.

J. B. Calva & Co., Consulting Engineers of Minneapolis, have developed a method for odorization of liquefied petroleum gas. The method, according to company announcement, has proved effective experimentally.

Ordinary procedure, the announcement said, involves the addition of ethyl mercaptan to the liquid phase, but the petroleum gas vaporizes much more rapidly than does the odorant.

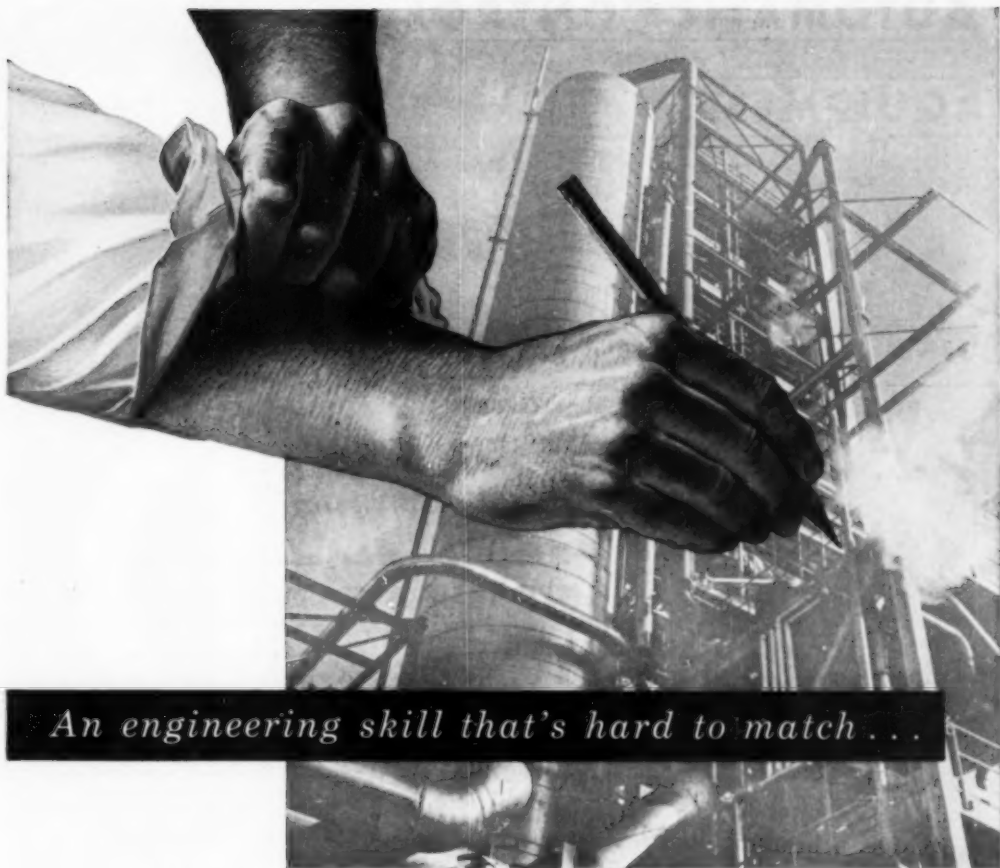
In the Calva process a small cartridge of odorant is inserted into a specially provided cavity in the valve of the cylinders. In this manner a liquefied petroleum gas is given a uniform concentration of odor and at a level of odorization comparable to that of utility service gas. The process is also applicable to semi-bulk installations and to central plants for utility service.

(More News on page 40)



Above is a view of the new general research laboratory of International Minerals & Chemical Corp. at Skokie, Ill. It was opened late in June.





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We mean the skill that's acquired after rolling up sleeves 600 times or more—to design and construct that many petroleum refining, petroleum chemical and chemical plants at sites all over the world.

These plants didn't just happen. Lummus men had ideas, practical imagination, the ability to work, a sharp sense of responsibility,

and a company policy which placed no limit upon the physical facilities needed to do the job.

All this is worth its weight in gold—an appraisal which our clients express time and again. We see it as a healthy "atmosphere" in which new processes, new techniques, new equipment and new products are developed to our own high standards, and

to the satisfaction and profit of our customers.

So we offer this suggestion: put us down as a group with the depth of chemical engineering talent and the breadth of experience to tackle *your* next engineering and construction project—whatever and wherever it may be. And to do it with a skill that's hard to match.



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# DATA SERVICE

## BULLETINS

1 • **MIXERS.** All types of grinding and mixing equipment of Paul O. Abbé, Inc.

2 • **GLUCOSATES.** D. W. Haering & Co., Inc., describe their complete chemical line. Information available.

3 • **TRANSITE PIPE.** For overhead piping systems. Data on transit pipe from Johns-Manville Sales Corp.

4 • **TANK-O-METER.** A new device, together with others, for measuring liquid level and tank contents from a distance. Uehling Instrument Co.

5 • **DESIGN OF CHEMICAL PLANTS.** Detailed description on this subject furnished by Chemical Construction Corp.

6 • **IMP MILL.** Combustion Engineering-Superheater, Inc., has a new Raymond Imp Mill for wide range of grinding operations.

7 • **EXPLOSION-PROOF LIGHTING UNITS.** For protective lighting in hazardous locations. Information detailed by Benjamin Electric Mfg. Co.

8 • **M-SCOPE.** The latest in pipe locating and leak-detecting devices. Fisher Research Laboratory, Inc.

9 • **ROTATING PAN-TYPE MIXER.** Open or dust-sealed for glass, fertilizer, refractories, enamel frits, candy, chemicals, etc. Worthington Corp.

10 • **PRESSURE SAMPLING CONTAINERS.** New in this field by Murray Tube Works. Containers can be supplied with any approved-type valves, plugs, etc.

11 • **CRUSHERS.** No. 13 series and special purpose crushers from American Pulverizer Co.

12 • **FLOATING ROOF TANKS.** Now

### EDITOR'S NOTE

For this month's Data Service, we are abandoning our usual extensive descriptions of bulletins. In order that a large backlog may be cleared away before the fall season, the editor here is listing only the subject of the publication, one-sentence description of its contents and the name of the company. Data service continues in operation as before, and if you wish any information on the material described, merely circle the number on the postcard and put it in the mail. Chemical Engineering Progress will take care of the rest.

available double-deck floating roof tanks for storage purposes from Graver Tank & Mfg. Co., Inc.

14 • **TESTING INSTRUMENTS.** Large variety of metering devices and accessories for testing paints, foods, lubricant greases, viscous materials, etc. Gardner Laboratory, Inc.

15 • **AIRCHECK VALVE.** Improved valve for use on air or gas compressor. No bolts, nuts or screws. New with Pennsylvania Pump & Compressor Co.

16 • **PFAUDLER EQUIPMENT AND SERVICES.** Buyer's guide giving information on glass-lined steel and stainless steel equipment. The Pfaudler Co.

17 • **CLAMPS, STRAPS, COUPLINGS.** Available in a wide variety of sizes and materials from Marman Products Co., Inc., and especially advantageous to those who build and maintain aircraft.

18 • **AUTOMATIC TEMPERATURE CONTROLS.** For a wide range of temperature control functions an electric pneumatic valve. Burling Instrument Co.

19 • **THERMAL CONDUCTIVITY UNITS.** An inexpensive means for rapid and accurate observation of gases in industry or the laboratory, from Gow-Mac Instrument Co.

20 • **FILTRATION MANUAL.** A 19-page comprehensive brochure on practical

Cards valid for only six months after date of issue

## Chemical Engineering Progress Data Service

I would like to obtain more information on the items represented by the numbers I have circled.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	
44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	
65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	
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August 1952

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# DATA SERVICE

cal evaluation of pilot plant and filtration data from The Eimco Corp.

**21 • AUTOMATIC DATA ANALYSIS.** Telecomputing Corp. brochure on how Telecomputing instruments save the time of engineers and scientists by analyzing data faster than is possible manually.

**22 • THE ACCELATOR.** Water treatment for domestic and industrial use. Complete details by Infilco, Inc.

**23 • COMPRESSOR FOR AMMONIA TRANSFER.** Worthington Corp. announces a new LPG-A compressor especially for transfer of anhydrous ammonia from tank car to storage tank.

**24 • TELLEVEL CONTROL SWITCHES.** Complete line of automatic, bin-level control switches. Explosion-proof and heavy-duty units introduced by Stephens-Adamson Mfg. Co.

**25 • WORM GEAR.** Catalog 45S from D. O. James Gear Mfg. Co. describes and details gears of many types and sizes.

**26 • KNIGHT-WARE.** A special ceramic which is tough, uniformly dense and corrosion resistant is the material from which this laboratory and plant equipment is made by Maurice A. Knight.

**27 • METERING FLOATS.** From Fischer & Porter Co. a bulletin on their Flowrator "area" flow meter, a predictable metering float. Available for immediate shipment.

**28 • POWER DRIVES.** Electric power drives engineered to your requirements available from Sterling Electric Motors, Inc.

**29 • DORR CLONE.** Cylindro-conical classification unit using centrifugal force in place of gravity, from The Dorrr Co.

**30 • MODERN pH AND CHLORINE CONTROL.** W. A. Taylor & Co. offer a 96-page booklet on this subject. Covers all phases.

**31 • LOW INTENSITY DRY BOX.** Of stainless steel for handling radioisotopes and other radioactive materials. Bulletin available from S. Blickman, Inc.

**32 • DEHUMIDIFIERS.** For instrument air-drying, bulletin on Sovabead dehumidifiers from Industrol Corp.

**33 • LEAKPROOF TUBE FITTINGS.** Catalog 4300 from The Parker Appliance Co. describes its Triple-Lok tube fitting said to be leakproof under high pressure, severe vibration of extreme temperatures.

**34 • AUTOMATIC FEEDER.** For use in plants where packaging is of paramount importance the B. F. Gump Co. offers its Bar-Nun Auto-Check weigher which opens feeds, weighs and ejects at the rate of 26 to 30 one-lb. bags per minute.

**35 • ICE-CEL UNITS.** Dole Refrigerating Co. offers a new catalog describing its vacuum cold plates for air conditioning and product cooling.

**36 • TAC AN INDUSTRIAL TOOL.** TAC is a ratchet, socket and open-end wrench all in one, being introduced by Tubing Appliance Co. for every use where a wrench is required.

**37 • BAKER CHEMICALS.** From J. T. Baker Chemical Co. a complete schedule of all its fine industrial chemicals, alphabetically arranged for easy use.

**38 • pH CONTROL.** The Foxboro Co. offers a new manual covering the expanded use of pH control in a variety of fields such as fertilizers, explosives, soap paint, etc.

**39 • ELEVATED STEEL TANKS.** Bulletin discussing water storage in five types of elevated steel tanks from Pittsburgh-Des Moines Steel Co.

**40 • HEAT-TRANSFER APPARATUS.** Illustrated presentation of some designs of heaters, coolers, condensers and heat exchangers of The Griscom-Russell Co.

**41 • PULVERIZERS.** Mead Mill Co. leaflet detailing its pulverizers for use on all grindable and ungrindable materials used in most industries.

**42 • FLOW-RATE REGULATORS.** W. A. Kates Co. offers a line of direct-acting flow-rate regulators for control of liquid flow wherever necessary.

**43 • DRUMS AND BARRELS.** A new catalog covering the full line of

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Hackney returnable drums and barrels from Pressed Steel Tank Co. Available in choice of materials.

**44 • SILASEAL.** A silicone-type transparent water repellent just announced by Surface Protection Co. Controls and eliminates effluence on masonry.

**45 • ELECTRONIC FLOW METER.** Instrumentation data sheet presents the new Potter-Brown flow meter by Minneapolis-Honeywell Regulator Co.

**46 • BETTER ANALYSIS.** Booklet devoted to applications of infrared analysis. Issued regularly by Baird Associates, Inc.

**47 • WELDING ANALYZER.** A new leaflet from The Brush Development Co. covers its welding analyzer which records graphically welding current, etc.

**48 • CHEM-REM.** New chemically resistant paint by Speco, Inc. Acid and alkali-resistant black paint with silicone additive for metal, wood, etc.

**49 • INSTRUMENTS DIGEST.** A re-issued bulletin augmented and brought up to date from Minneapolis-Honeywell Regulator Co. Includes items not previously covered and latest spectrometers, potentiometers, densitometers, etc.

**50 • STATIONARY-CONTROL.** Four-page leaflet giving dimensions and engineering information on wide-range, stationary-control Vari-Pitch sheaves with new type Magic Grip bushing for use with Q or R section belts. Allis-Chalmers Mfg. Co.

**51 • MIXERS.** Struthers Wells Corp. has just issued a new bulletin covering intensive mixers, dispersion machine kneading machines, etc., for wide range of materials.

**52 • MULTI-LOUVRE DRYERS.** For use wherever rapid and uniform drying, cooling and processing of bulk materials is desired. Link-Belt Co. offers

a new, descriptive booklet on its complete line.

**53 • AMESTEAM GENERATOR.** Bulletin No. 1050 from Ames Iron Works gives full details on Amesteam generators. Can be connected to purchaser's steam, water, fuel and electric lines and to his breeching or stack. Ready to operate.

**54 • STAINLESS STEELS.** A 32-page booklet from International Nickel Co., Inc., gives extensive data on the corrosion-resisting properties of Austenitic chromium-nickel stainless steels.

**55 • ODORIZATION OF LPG.** A solution for odorization of LPG in the liquid phase is given in bulletin G-5 from J. B. Calva & Co.

**56 • BRUSH-ON FURAN LINING.** Carbo-Kote 6020, a thermosetting furan coating which can be brushed or sprayed for resistance to corrosive chemicals. Bulletin from Carboline Co.

**57 • SMOKE CONTROL.** Methods of guarding against panic and damage from smoke by use of Ess Instrument Co. air-conditioning smoke indicators listed in new bulletin.

**58 • INFRA-RED ANALYZER.** Designed by Mine Safety Appliances Co. for use in rapid automatic analysis of fluid mixtures, precise control of processes, etc.

**59 • ARIDIFIER.** Logan Engineering Co. announces the Aridifier, a mechanical cleaner, said to remove 92% of oil, moisture or dirt from compressed gas and air lines.

**60 • MODERNIZED ROLL SERVICE.** A special service for reconditioning rolls guaranteeing more uniform corrugations and speedy return of rolls to manufacturer. Sprout-Waldron & Co., Inc.

**61 • PITTSBURGH ELECTRODRYER CORP.** New 32-page bulletin on how de-

humidifying equipment solves moisture problems for industry.

**62 • ECONOMICS IN RESEARCH.** Battelle Memorial Institute offers a blueprint for planning to those interested in research in engineering economics.

**63 • PERMANITE.** A furfuryl resin manufactured by Maurice A. Knight for fabrication of corrosion-proof chemical equipment. Special designs available.

**64 • GALVANITE.** Coating for iron or steel surfaces. Creates an electrochemical union uniting zinc with base metal's surface. Galvanite Corp.

**65 • BURNERS.** Refrak screen burners, tunnel-type multiport gas burners for furnace or open-firing. Designed to operate with pressurized mixtures of any fuel gas and air. Selas Corp. of America.

**66 • BROWN CONVERTERS.** From Minneapolis-Honeywell Regulator Co. detailed instrumentation sheet on Brown converters, synchronous, a.c. driven vibrators.

**67 • ALCOHOL LOSS RECORDER.** Designed to measure accurately and continually record loss in alcohol slops. Minneapolis-Honeywell Regulator Co.

**68 • O-RINGS.** Molded from Parkone, a special compound of the Parker Appliance Co. These rings are extremely resistant to ambient temperatures of -100° F. to +500° F. Also useful in static sealing where resistance to oxidation is required.

**69 • DUST CONTROL.** Most comprehensive brochure from American Wheelabrator & Equipment Corp. Tells how cloth-type dust collectors handle complex problems.

**70 • BALL BEARINGS.** More than 120 types and sizes of miniature ball bearings listed in a new catalog from Miniature Precision Bearings, Inc.



**71 • GAUGES.** New specification sheets from Minneapolis-Honeywell Regulator Co. describe indicating and pressure gauges, some with pneumatic control.

**72 • GLOSSARY ON IRON.** For producers and users of iron castings, International Nickel Co., Inc., has issued a 36-page glossary of terms commonly used in this field.

**73 • DIAPHRAGM VALVES.** Both single-seated and low-flow valves detailed and described by Minneapolis-Honeywell Regulator Co.

**74 • SLUDGE CONTROL.** Modern instrumentation controls for air and return sludge in municipal and industrial activated sludge plants. The Foxboro Co.

**75 • RADIOACTIVE EQUIPMENT.** Nuclear Instrument & Chemical Corp. describes latest instruments and radiochemicals for radioisotope applications.

**76 • ROLLER CHAIN.** A new 150-page extensive and comprehensive catalog on roller chains and their application. Link-Belt Co.

**77 • ACID-PROOF MATERIALS.** In three new bulletins Aqua-Therm, Inc. gives all details concerning Fonite pipe and fittings made of furan resin material reinforced with laminations of chemical glass fabric cloth. Acid-proof construction.

**78 • OIL-TIGHT CONTROLS.** The Arrow-Hart & Hegeman Electric Co. has a complete new line of oil-tight interchangeable push-button controls to protect machines from spray or flood of oil.

**79 • FILM BADGE SERVICE.** An inexpensive weekly service for measurement of personnel exposure to radiation from radioactivity, x-rays, or radium. Issued by Tracerlab, Inc.

**80 • SUB-A FLOTATION.** A new process for reclaiming waste paper and floating away ink and other impurities. Denver Equipment Co.

**81 • CORROSION-PROOF CEMENTS.** Technical data and catalog information on four basic types of corrosion-proof cements on installations where acids, alkalis, solvents, etc., are used. Atlas Mineral Products Co.

**82 • COOLING TOWERS.** Illustrated brochure giving details and cutaway views of cooling towers of various types made by Hudson Engineering Corp.

**83 • BUILDING BLOCKS.** Unitized optical and electronic components capable of dealing with problems on monochromatic light, a new concept of research instrumentation. Discussed in a bulletin from The Perkin-Elmer Corp.

**84 • TABLETTING PRESSES.** From F. J. Stokes Machine Co. catalog covering tableting presses for the pharmaceutical, powder metal and other industries.

**85 • INDEX.** Minneapolis-Honeywell Regulator Co. offers a complete index of all its technical publications listed both numerically and alphabetically.

**86 • D-I CELL.** From The Dorr Co. this new cell for use in ion-exchange systems has two advantages, level control and air-dome system the use of which provides minimum dilution of the solution treated.

**87 • THERMOCOUPLES.** Complete line of standard assemblies and parts extensively treated in a new catalog from Leeds & Northrup Co.

**88 • SECTIONAL LABORATORY FURNITURE.** All that is new and attractive in sectional laboratory furniture covered in a bulletin from Labline, Inc.

**89 • STAINLESS STEEL FASTENINGS.** All types of screws, nuts, bolts, washers, etc., described and illustrated in a new catalog from Star Stainless Screw Co.

**90 • PROPORTIONING PUMP.** For full information on line of mechanical drive U-type metering and proportioning pumps, a catalog from Hills-McCanna Co.

**91 • AGILE PLASTICS.** A complete line of corrosion-resistant plastic pipe, tubing, and fittings manufactured by American Agile Corp.

**92 • LATTICE-BRAID PACKINGS.** A new type of braided packing braided internally as well as externally by The Garlock Packing Co. Unusual strength and durability claimed.

**93 • SMOKE PERISCOPE.** Especially interesting to marine and industrial engineers. Ess Instrument Co. has a Wyd-Angle smoke periscope with 90° vision angle for checking on stacks, etc., out of line of vision.

**94 • MAINTENANCE SERVICE.** Metalweld, Inc. Catalog describes its services for industry. Protective coating, rubber lining, metal spraying, etc.

**95 • SPRAY NOZZLES.** Made of brass or special corrosion-resistant materials for use in chemical sprays or chemical processes. Manufactured by Binks Mfg. Co.

**96 • FOAMGLAS.** Specifications for the application of this material to cellular glass insulation discussed in a booklet from Pittsburgh Corning Corp.

**97 • ICING EQUIPMENT.** Published by Link-Belt Co. a book which describes and discusses icing equipment manufactured by this firm.

**98 • ELECTRIC TRACTOR.** For industrial towing applications where a heavy-duty electric tractor is required. Model MT worksaver described in folder from Yale & Towne Mfg. Co.

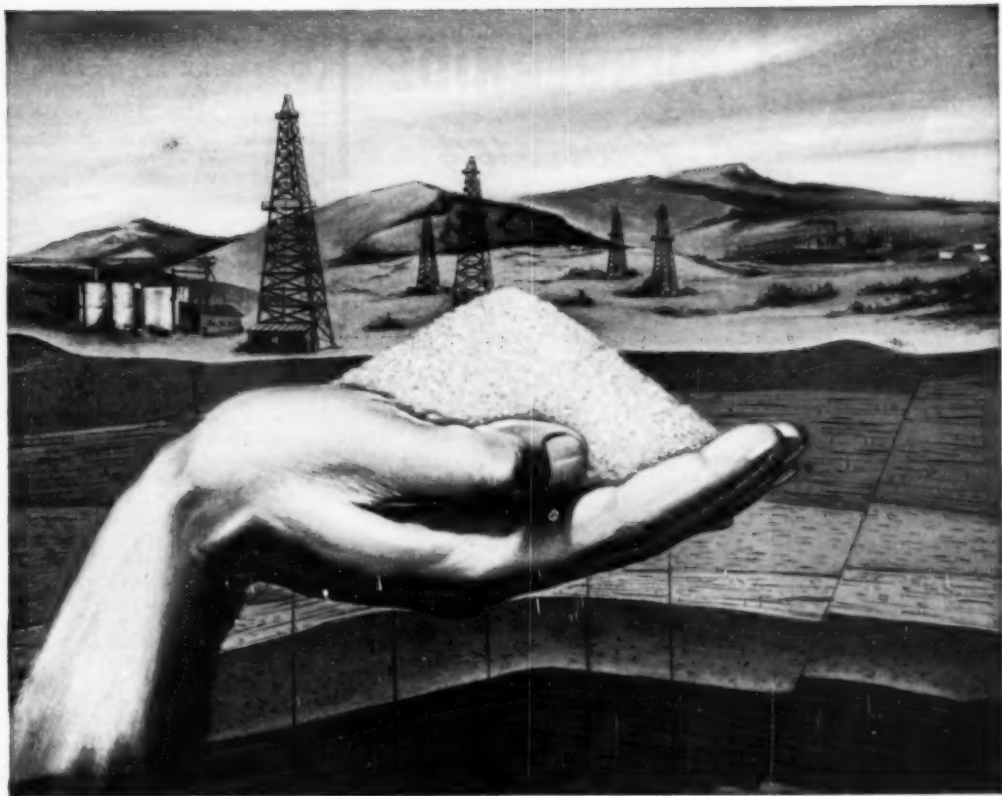
**99 • PUMPS.** Details of controlled volume air-operated pumps and chemical feed systems manufactured by Milton Roy Co. described in new 2-color bulletin.

**100 • PRODUCTION CONTROL.** How to use punched-card tabulating equipment, Sched-U-Graph and Kardex units for effective production control, a bulletin from Remington Rand, Inc.

**101 • KOROSEAL BULLETIN.** From Metalweld, Inc., a bulletin telling why tank linings remain soft and pliable even with strong oxidants when Korosealed.

**102 • METRON TACHOMETERS.** Analyzes the principles of operation of Metron hand, portable and fixed installation tachometers. From Metron Instrument Co.

**103 • TRI-ROTOR PUMPS AND PARTS.** Engineering data, descriptions of all models of pumps from 20 to 200 gal./min. Manufactured by Yale & Towne Mfg. Co.



## "Lift-up powder" for tired oil wells

**How Celite  
filtration  
helps boost  
oil output**

To BOOST THE OUTPUT of "tired" oil wells bordering on the limit of economic production, profit-conscious operators inject water under extreme pressure into the porous oil sandstone and force out the accumulated oil. But first, they filter this repressurizing water with Celite® to remove the suspended solids which would eventually clog the microscopic pores of the sandstone, thus blocking the flow of water. *All waters contain at least a trace of these troublesome impurities.*

Celite's ability to do an exceptional filtering job can be attributed to these important factors which make it unique among filter aids:

Carefully processed from the purest deposit of diatomaceous silica known, Celite is available in nine standard grades—each designed to trap out

suspended impurities of a given size and type. Whenever you reorder, you are assured of the same uniform, accurately graded powder received in your initial order. Thus, with Celite, you can count on consistent clarity in your filtrates—at highest rate of flow—month after month, year after year.

The secondary recovery of oil by water flooding is just one of many processes in which Celite has provided the absolute clarity vital to a successful operation. The proper grade of Johns-Manville filter aid will assure you the same results—regardless of the product or process involved. To have a Celite Filtration Engineer study your problem and offer recommendations, simply write Johns-Manville, Box 60, N.Y. 16. No cost or obligation.

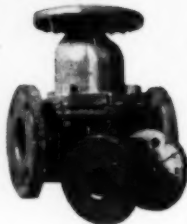
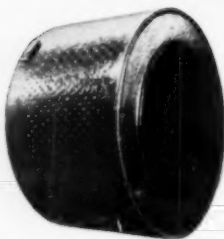
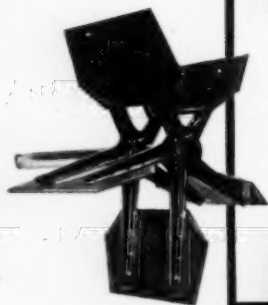
\*Reg. U. S. Pat. Off.



**Johns-Manville CELITE**  
**FILTER AIDS**

# "RUBBERHIDE"

## Processed LININGS...



## Proven Protection Against Corrosion and Abrasion

"RUBBERHIDE" is a special Goodall formula for linings processed to exterior or interior surfaces of all types of metal equipment to provide long-lasting protection from corrosion and abrasion. The selected rubber or synthetic compound is inseparably bonded to the metal, in any required thickness. There is virtually no limitation as to size, shape or service requirement of the metal parts or products involved. Factory processed in Trenton, N.J. or Chicago, Ill.; or application by field crews for large or permanently installed units.



## GOODALL RUBBER COMPANY

GENERAL OFFICES, MILLS and EXPORT DIVISION, TRENTON, N. J.

Branches: Philadelphia • New York • Boston • Pittsburgh • Chicago • Detroit • St. Paul • Los Angeles • San Francisco • Seattle • Portland • Salt Lake City • Denver • Houston • Distributors in Other Principal Cities

**GOODALL RUBBER COMPANY**  
4 WHITEHEAD ROAD, TRENTON 4, N.J.  
Please send Booklet on Linings for Corrosion and Abrasion Control.

Company \_\_\_\_\_  
Address \_\_\_\_\_  
City \_\_\_\_\_ Zone \_\_\_\_\_ State \_\_\_\_\_  
Att. of \_\_\_\_\_

Mail coupon for Illustrated Booklet, or submit details of conditions to Goodall Corrosion Engineers for recommendations. Prompt cooperation assured.



## NEWS

(Continued from page 32)

### GLYCERINE APPLICATION AWARD FOUNDED

The Glycerine Producers' Association announced last month the establishment of a group of awards for outstanding research in the application of glycerine or glycerine derivatives. The awards to be given will consist of an honor plaque carrying a cash stipend of \$1,000, and two honor certificates carrying stipends of \$300 and \$200 respectively.

In announcing the awards, E. Scott Pattison, manager of the Glycerine Producers' Association stated the awards were established for the purpose of acknowledging and encouraging research which advances still further the uses for glycerine and its derivatives in any product for industrial or consumer use.

As outlined by the Association, research work eligible for nomination may be concerned with chemical, physical, or physiological properties of glycerine, or with properties of glycerine-containing or glycerine-derived materials. The work may deal with applications which of themselves are currently or potentially of value to industry or the general public, or it may deal with scientific principles.

### CHAS. PFIZER SUBSIDIARY IN BRAZIL

Establishment of Pfizer Inter-American, S. A., a subsidiary of Chas. Pfizer & Co. which will process and distribute antibiotics and other pharmaceutical products in Brazil, was announced in Rio de Janeiro last month by John E. McKeen and John J. Powers, president and vice-president, respectively, of the Brooklyn firm. The plant for the subdividing and processing of Pfizer products will be in Sao Paulo and headquarters in Rio de Janeiro.

In addition to a full range of antibiotics, the new plant will be equipped to process other new medicinal products such as Cotinazin, Pfizer's brand of isonicotinic acid hydrazide, now being widely tested against tuberculosis.

Previously Fursland Laboratories had distributed the Pfizer antibiotics in Brazil. Recently, however, arrangements were made with Fursland to collaborate with Pfizer in the establishment of the new Brazilian company.

### PLATE EFFICIENCIES

(Continued from page 30)

Kinckner, Du Pont; H. L. Malakoff, Cities Service Research & Development Co.; G. T. Skaperdas, M. W. Kellogg Co.; Manson Benedict, M.I.T.; H. E. O'Connell, Ethyl Corp.; J. W. Mayers, Sharples Chemicals, Inc.

# A New Achievement

.... in simplified,  
automatic Tank Gauging



**"Varec"** FIGURE NO. 2500  
AUTOMATIC  
TANK GAUGE  
FOR ALL TYPES OF LOW PRESSURE TANKS  
READINGS UP TO 70 FT.

"VAREC", a pioneer in the development and manufacture of automatic tank gauging equipment has applied new fundamentals of design and operation to the Figure No. 2500 Gauge for the ultimate in accurate liquid level reading and dependable, trouble free operation.

Representing a major improvement with this new concept of simplified automatic tank gauge design, the "VAREC" Figure No. 2500 now utilizes the revolutionary Neg'ator Motor (Pat. No. 2,063,799) housed within the gauge head, to maintain a predetermined constant tape tension. This eliminates the need for a conventional counterweight.

Here's a  
Look Box  
You Can Read  
Easily,  
Accurately!

(Shown approxi-  
mately 1/2 actual  
size)



#### EASIEST TO INSTALL because:

Both counterweight and counterweight pipe have been eliminated. This permits installation of the look box at any desired height from the ground or on top of tank.

#### EASIEST TO READ because:

Full view Counter in the Look Box for quick, accurate reading of foot increments and a dial for reading inches and fractions. Use of large distinct numerals minimizes chance of reading errors. Eliminates calibrated tape.

#### EASIEST TO OPERATE because:

"VAREC" patented Gravity Compensator (Pat. No. 1879805) is incorporated with "inch reading" dial. An external Gauge Check device (Pat. No. 2555593) permits manual checking of gauge operation when desired.

#### EASIEST TO MAINTAIN because:

All internal parts of the Figure No. 2500 Look Box are non-sparking in contact with each other. Non-corrosive Graphitar tape sheave bearings — self lubricating.



THE VAPOR RECOVERY SYSTEMS COMPANY  
2820 N. Alameda Street, P. O. Box 231  
Compton, California, U.S.A.

The "VAREC" Figure No. 2500 Automatic Tank Gauge is gas tight. It is adaptable to all types, arrangements and installations of low pressure tanks up to 70 feet in height. "VAREC" Figure No. 2500 Gauge Head is available as a separate unit and can be installed on existing float operated type tank gauges utilizing 3/8" wide tape sheaves.

Provision has been made on the Look Box housing for installation at any later date of a "VAREC" Electronic Remote Reading Gauger Transmitter for use in conjunction with the various models of "VAREC" Electronic Gauger Receivers.

If you are not yet realizing the many time and money saving features and advantages of automatic tank gauging in your operations, install this new, simplified "VAREC" Figure No. 2500 Automatic Tank Gauge and start out ahead. Write or call your nearest "VAREC" Representative for all the facts.

MAIL COUPON NOW FOR NEW BULLETIN CP-3500

THE VAPOR RECOVERY SYSTEMS COMPANY  
2820 N. Alameda Street, P.O. Box 231  
Compton, California, U.S.A.

Dept. \_\_\_\_\_

Name \_\_\_\_\_ Title \_\_\_\_\_

Street and No. \_\_\_\_\_

City and State \_\_\_\_\_

CEP

# MARGINAL NOTES

News of Books of Interest to Chemical Engineers

## The Sheepskin Crowd

**They Went To College.** Ernest Havemann and Patricia Salter West. Harcourt Brace & Co., New York (1952) 277 pp. \$4.00.

**THEY Went To College** is fascinating, especially so for engineers with their mania for figures and statistics. The volume is a study of the college graduate in America today, and the data were accumulated from a survey run by Time Magazine in 1947.

The very manner in which the survey was thought out is in itself interesting enough for comment. Time asked all the degree-granting institutions in the United States for the names of all graduates whose last name began with Fa. They then quizzed these graduates via a questionnaire, and of the 17,000 who were polled, some 9,064 answered the thirteen pages of questions. The tabulated results are manna for minds with an appetite for facts. In the matter of salary, the book points out there are certain quite positive financial returns that can be shown to each college graduate. In the first place they hold the more important jobs in our society. For college graduates, median income, for men, was \$4689 against the average for all American men that year, \$2200.

As the authors of the book point out, the salary of a college man under thirty is higher than the highest point reached at any age by the non-college group. Then too, between the ages of thirty-five to forty-four the earnings of the non-college group drop after a peak of about \$2845, whereas the income of the college graduate, instead of dropping after forty, as does the non-college man, continues to increase.

There is not too much in the book concerning the earnings of engineers. Law, medicine and dentistry seem to be, from this study, the highest paid professions; some 62% of the male graduates in these fields earned more than \$5000. This compares with the 52% of the engineers who earn more than \$5000.

One of the book's most important items in the study of earnings shows that graduates of the "Big Three," Harvard, Yale or Princeton, earned about \$1200 more a year than their nearest college contemporaries from other Ivy League colleges such as Columbia, Cornell, Dartmouth, and Pennsylvania. The technical schools were practically \$2000 below the

"Big Three" in terms of earning power.

Salaries are actually a minor part of the study. The bulk of the book is given over to other more sociological facts and these are themselves quite important. One conclusion derived from the study is that doctors are the most envied, and are the most satisfied in what they have done. Only 9% wish they had studied something other than medicine, whereas 19% of the engineers wish they had studied a different type of engineering. Medicine, on the other hand, was the field most frequently envied by the minority dissatisfied with their present status in law, agriculture, forestry, history, literature, language, and pharmacy. In these latter two studies, one third of the graduates wished they had chosen a different profession. Thirty per cent of the business administration graduates wished they had taken engineering, whereas a similar percentage out of education and social sciences wished it had taken business administration. As the editors winsomely sum up, "... on second thought, sometimes the grass is greener."

For those who are at all analytical about their lives and their education, and possibly the future of education, this is a book to be studied and to be read. The illustrations and charts are clear, with a light, deft touch and one does not have to go through much of the text in order to understand them.

Thumbnailing the rest, the book covers studies of the religious, political and marital experiences, preferences and prejudices of college graduates. It weighs the ex-co-ed; tells what sort of a wife she makes; what a career means to such a woman; what the chances of success are as careerists. It discusses what happens to the "greasy grind" in college versus the "campus bigshot"; what happens to the religious beliefs of graduates; the number who are apt to vote Republican; the effect on ones politics of getting an education in one state and working in another; in short, this is by far the most complete study of an important segment of our society, the college graduate. For educators it is required reading; for engineers with a professional slant on their education and profession it will help to bring home many facts that one suspected before, but which have never been held up to the impersonal analysis of an IBM machine.

—F.J.V.A.

## What Is Patentable?

**Patents for Technical Personnel.** Dr. Worth Wade. Chemonomics, Inc., New York. (1951) 40 pp. \$3.00.

*Reviewed by P. L. Young, Patent Div. Standard Oil Development Co., Elizabeth, N. J.*

**THE** management of research and development groups is continually facing the problem of impressing the importance of patents upon technical personnel. Many companies prepare for their own use manuals containing such information, but no convenient booklet has been heretofore available for the public. Dr. Wade has prepared such a manual, presumably by a hurried revision of one of the private industrial counterparts. As such, it is a helpful beginning; but it seems a pity, in view of the obviously great need for such a publication, that it was not done with greater care.

The author explains briefly what constitutes a patentable invention, what a patent is and how it is obtained, and includes discussions of patent department organization and the steps involved in keeping proper records. Hints on how to read and interpret patents are also included.

Just what to include in a book of this sort is difficult to decide and is, of course, the product of the author's experience and preference. In this instance, it appears to this reviewer that certain fundamentals such as the discussion of patentability, reduction to practice, diligence and the difficulties of corroboration are unduly brief and should be expanded and illustrated by specific examples. The inclusion of a good bibliography would help further to increase the reference value of this publication.

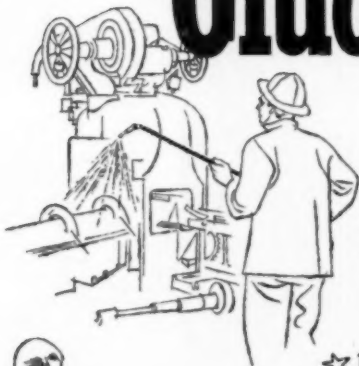
This reviewer believes that the emphasis is not well placed in this book. The real need to be met is to explain the fundamentals of patent law with respect to the situations which arise directly in the work of the technical man and with which he himself must deal. In these matters the book should be sufficiently detailed and illustrative to serve as a sound guide to the technical man. It is felt that Dr. Wade's book, while adequate, does not do this to the desired extent and in certain portions is not

(Continued on page 54)



## What Properties in an Acid Do You Need Most?

# Gluconic Acid is



### ☆ Non-corrosive!

Extensive laboratory tests have shown Gluconic to be the least corrosive of the mild acids.

### ☆ Non-toxic!

Other tests have demonstrated this acid's non-toxicity. It is widely used in pharmaceutical preparations.



### ☆ An Effective Sequestering Agent!

Inactivates metallic contaminants. Keeps trace metals from precipitating out of solution.

These properties explain why Gluconic is a versatile acid. It is used widely as an ingredient of cleaning compounds, particularly those used for food and beverage equipment, and is effective in beerstone prevention. It is used in the textile industry as an acid catalyst for vat soluble ester printing pastes and as a sequestering agent to give sharper prints in dyeing operations. It is also used as a sequestering agent in tanning and in industrial water treatment.

Gluconic acid may be the mild, non-toxic acid you have been looking for. It may help improve your present processing operations or suggest new ones. Additional information is contained in Technical Bulletins Nos. 29 and 33. Write:

**CHAS. PFIZER & CO., INC.**

630 Flushing Ave., Brooklyn 6, N. Y.

425 North Michigan Ave., Chicago 11, Ill. 605 Third St., San Francisco 7, Calif.

*Manufacturing Chemists  
for Over 100 Years*



# PFIZER

# CORROSION-PROOFED BY PENNSALT



**For 13,200 hours . . .  
this room has handled  $H_2SO_4$ ,  
saturated with chlorine**

This room is a good example of Pennsalt anti-corrosion know-how. It is *our own room*, protected by Pennsalt products, at our Wyandotte, Michigan, plant.

Notice the "new" look about this room—despite the fact that for a year and a half it has been continuously handling highly corrosive sulfuric acid saturated with chlorine.

This is the kind of results you can expect when you take your corrosion problems to Pennsalt . . . a company that not only makes anti-corrosion products, but also lives with the same type of corrosion problems you yourself do.

Thorough-going research, plus many years of sales-engineering experience, combine to offer you 15 different corrosion-resistant cements, as well as paints, to meet your needs. From the floor to the top of your smokestack, we can offer you qualified counsel and job-proved products to lick the problem. Write: Corrosion Engineering Products Department, Pennsylvania Salt Manufacturing Co., Phila. 7, Pa.

**Pennsalt  
Chemicals**

## Secretary's Report

S. L. TYLER

The Executive Committee met July 11 at The Chemists' Club, New York. The Minutes of the June Meeting and the Treasurer's report were accepted and bills were approved for payment.

Those candidates for membership whose names were published in the June issue of "C.E.P." were elected; also seventeen Student members were elected.

A few appointments of personnel to the Local Sections Committee, Nuclear Energy Committee and Public Relations Committee were made on recommendation of the respective committee chairmen. A new committee, to be known as the Vocational Guidance Committee, consisting of Z. G. Deutsch, chairman, W. D. Kohlins and C. B. Roen was established.

In accordance with invitation received from the Yale University School of Engineering to celebrate the Centennial Year of Yale School of Engineering, Oct. 24, 1952, S. L. Tyler was appointed the official representative of the Institute.

Secretary reported receipt of a surplus of \$509.37 from the Atlanta meeting and \$800.34 surplus from the French Lick meeting, and it was voted to credit this money to the Institute Meetings Account.

Resignations of five Junior members from membership were accepted.

The name of William H. Ailor was placed on the Suspense List at his request on entry into the Armed Forces.

The name of the recently authorized local section of the Institute with headquarters in Atlanta has now been officially changed to the Atlanta Section of the Institute.

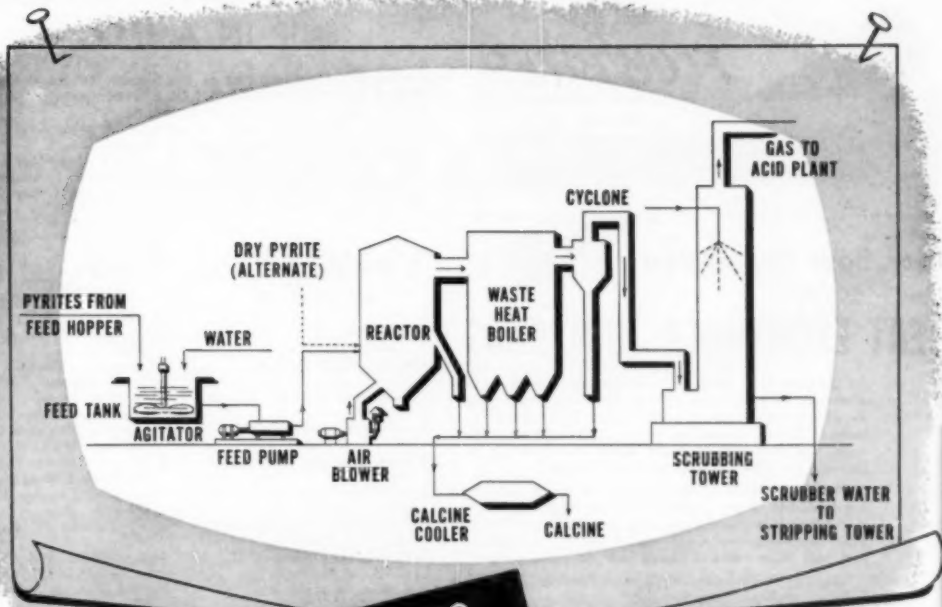
The Council met in the afternoon of July 11 at The Chemists' Club. W. C. Asbury, chairman of the Patents Committee, and L. C. Kemp, chairman of the Committee on Admissions, presented interim reports of their committees which were received favorably.

The Minutes of the previous meetings were approved.

Discussion of the financial obligations of Officers and Directors incurred by their attendance at Council Meetings led to the following decision by the Council:

When cost of travel might prevent a member from assuming the duties of an Officer or Director, transportation expenses may be authorized for that member to not more than four meetings of Council per year. Transportation expenses will not be paid for attending Council Meetings held in connection with national meetings.

(Continued on page 60)



**Now...HIGH STRENGTH SO<sub>2</sub>  
and accurate temperature control**

**from sulphide roasting  
... with the Dorco FluoSolids System.\***

Sulphuric acid manufacturers faced with a shortage of elemental sulphur are finding in FluoSolids an economically feasible means of tapping sulphides as an alternate source of SO<sub>2</sub>. Fifteen FluoSolids Systems are now under construction to furnish SO<sub>2</sub> gas for contact acid plants.

For detailed information about FluoSolids — a distinct departure from conventional roasters — ask for a copy of Dorco Bulletin No. 7500. Just write to The Dorr Company, Stamford, Conn., or in Canada, The Dorr Company, 80 Richmond St. West, Toronto 1.

\*FluoSolids is a trademark of The Dorr Company, Reg. U.S. Pat. Off.

*Facts* on FluoSolids Systems  
for SO<sub>2</sub> Production...

**Gas Strength** will average 10-15% SO<sub>2</sub> from pyrite and other sulphides.

**Gas Cleaning Equipment** is smaller than with conventional methods.

**Feed** can be coarse or very fine — dry or wet.

**Low Maintenance** because no moving parts are exposed to high temperatures.

**No Extraneous Fuel Needed** once calcining temperature is reached.

**Complete Instrumentation** minimizes the "human factor" in operation.



Better tools TODAY to meet tomorrow's demand

**DORR**

WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT

THE DORR COMPANY • ENGINEERS • STAMFORD, CONN.  
Offices, Associated Companies or Representatives in principal cities of the world.



## Low Cost Protection for HEAT EXCHANGER TUBE ENDS

In the past 31 years Consco has provided millions of Flowrites for tube inlets of heat exchangers operating in all industries and all applications. Tube inlets become eroded and worn long before the remainder of the tube, and by reinforcing the inlets it is possible to increase the effective tube life many times.

Flowrites—made of the same metal as the tubes—are available in any length, diameter or gauge. They are easy to install and remove by unskilled help. When Flowrites themselves become worn (instead of the tubes!), just pull them out and install new, longer Flowrites.

Get the facts from the 8-page Flowrite "proof" booklet, available upon request.

## CONDENSER SERVICE & ENGINEERING CO.

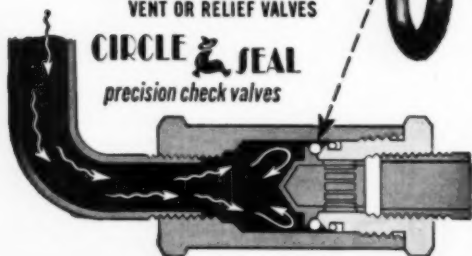
### the circle seal principle

provides sealing assurance  
never before offered in

### CHECK VALVES

VACUUM BREAKERS  
SENSITIVE LOW PRESSURE  
VENT OR RELIEF VALVES

CIRCLE SEAL  
precision check valves



**JAMES-POND-CLARK**

1247 East Green Street, Pasadena 1, Calif.

Engineering data  
sent free of charge  
on request.

## CANDIDATES FOR MEMBER- SHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before September 15, 1952, at the Office of the Secretary, A.I.Ch.E., 120 East 41st, New York 17.

### APPLICANTS FOR ACTIVE MEMBERSHIP

Accountius, Oliver E.,  
Columbus, Ohio  
Beuther, Harold, Pitts-  
burgh, Pa.  
Bookout, A. R., Jr., Bruns-  
wick, Ga.  
Brailsford, George W.,  
Houston, Tex.  
Currie, Mac A., Irvington,  
Calif.  
David, Lawrence J.,  
Charleston, W. Va.  
Fifer, Harvey R., Los  
Angeles, Calif.  
Firsatenberger, Burnett G.,  
Orchard Park, N. Y.  
Heilman, Joseph A.,  
St. Albans, W. Va.  
Hills, Cecil W., Jr.,  
Shawinigan Falls, Que.,  
Canada  
Hudig, J., Pasadena, Tex.  
Huntress, C. O., Kansas  
City, Mo.  
Jones, Bruce, Louisville,  
Ky.  
Kollgaard, Reynier, Phila-  
delphia, Pa.  
Lowman, William M.,  
Charleston, W. Va.  
Meyer, Fred J., Brooklyn,  
N. Y.  
Reitz, Charles F., Charles-  
ton, W. Va.  
Shields, J. R., Pittsburgh,  
Pa.  
Shipley, Thomas N.,  
Charleston, W. Va.  
Stokely, Dave R., Kings-  
port, Tenn.  
Thiede, Richard C.,  
Cranford, N. J.  
Tyner, Mack, Gainesville,  
Fla.  
Warner, William III,  
Charleston, W. Va.  
Wellford, Landon C.,  
Charleston, W. Va.  
Whipp, James V., Downey,  
Calif.

### APPLICANTS FOR ASSOCIATE MEMBERSHIP

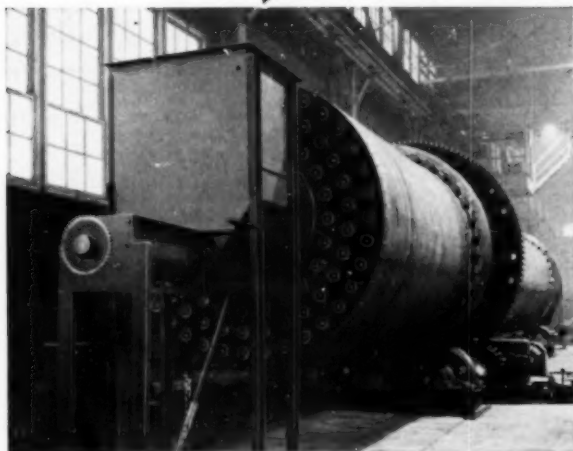
Brick, Bayard R., St. Louis,  
Mo.  
Holley, Herschel Q.,  
Huntsville, Ala.  
Mengert, William L.,  
Baton Rouge, La.  
Willard, M. C., Christians-  
burg, Va.

### APPLICANTS FOR JUNIOR MEMBERSHIP

Aldrich, Robt. F., Aurora,  
Ohio  
Ammerman, Thomas W.,  
Jr., Pasadena, Tex.  
Anderson, Floyd J., Jr.,  
Cleveland, Ohio  
Anderson, Maynard L.,  
Detroit, Mich.  
Anthony, Charles B.,  
Hasbrouck Heights, N. J.  
Apperson, Charles H.,  
Decatur, Ala.  
Arbit, Harold A., Boston,  
Mass.  
Ayers, William R., Wil-  
mington, Del.  
Bahlke, Herbert, Jr.,  
Chester, Ind.  
Baker, Ralph L., Bradley,  
Ark.  
Baker, William J., Jr.,  
Glen Burnie, Md.  
Ball, William E., St. Louis,  
Mo.  
Ballard, Louis H., Texas  
City, Tex.  
Bates, Ralph Neil,  
Wyandotte, Mich.  
Bauer, Donald, Detroit,  
Mich.  
Bauman, Ralph E., Chicago,  
Ill.  
Bean, Arthur R., Jr.,  
Beverly, Mass.  
Beauchair, Gaston, Jr.,  
New Orleans, La.  
Behrens, Martin A., Jr.,  
Alton, Ill.  
Beiler, Richard F., Lang-  
horne, Pa.  
Benny, Arthur L.,  
Compton, Calif.  
Berger, James W., Lincoln  
Park, N. J.  
Berlin, Norton H., Great  
Neck, N. Y.  
Berman, Herbert L.,  
Brooklyn, N. Y.  
Beyer, John H., Panama  
City, Fla.  
Birk, Kenneth L., Pasadena,  
Tex.  
Bodine, James E., Jr.,  
Spokane, Wash.  
Bohn, Louis A., Rochester,  
N. Y.  
Bonner, John S., Baytown,  
Tex.  
Boone, Merrill E.,  
Aaronburg, Pa.  
Bosworth, W. H., Jr.,  
Orange, Mass.  
Boyer, Lyndon D., Bartles-  
ville, Okla.

(Continued on page 48)

# New Dryer Requires the ACCURACY & UNIFORMITY of *Carpenter* Stainless Tubing



**M**odern process equipment like this rotary steam-tube dryer has to *stay on the job*. You can't afford to interrupt a process for hours or days to replace tubes.

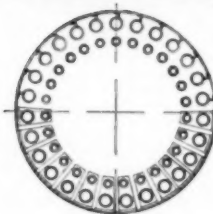
That's why—after considering several sources—this manufacturer's orders call for Carpenter Stainless Tubing. He knows that the quality standards we set at the mill will safeguard the quality reputation of his equipment.

Analysis, Tolerance and Finish are guaranteed to be "as ordered" on every shipment of Carpenter Stainless Tubing.

## THE CARPENTER STEEL COMPANY

Alloy Tube Division, Union, N. J.

Export Dept.: The Carpenter Steel Company,  
Port Washington, N. Y.—"CARSTEELCO"



♦ Cross-section view shows how Carpenter Stainless Tubing is arranged in concentric circles. Tubes in the inner circle are smaller diameter than outer tubes, to provide clearance and prevent lumps of material from wedging between tubes.

# Carpenter

## STAINLESS TUBING



—guaranteed on every shipment



# Now available

a new improved  
plastic diaphragm...



## "L-2" diaphragms offer new high standards of performance in many severe services

For a wide variety of severe services, including the valving of 66° Bé sulfuric acid, the new, improved "L-2" diaphragm offers physical and service characteristics never before available. Like its predecessor, the "L-1", the "L-2" diaphragm is made of polyethylene specially compounded to provide high resistance to strong acids and other highly active materials.

Hills-McCanna diaphragm valves with "L-2" diaphragms are available with a choice of manual, remote or automatic operators and with bodies of any machinable alloy or with rubber, Neoprene, glass or lead linings. Sizes range from 3/4" through 14". "L-2" diaphragms permit operation at temperatures to 125°F and pressures to 100 psi. Other diaphragms available are Kel-F, Neoprene, rubber, Hycar, Tygon, and butyl. Depending on material, these may be used at pressures to 150 psi, temperatures to 220°F.

Write for complete details. HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Ill.

## HILLS-McCANNA

*saunders patent diaphragm valves*

Also Manufacturers of Proportioning Pumps  
Force Feed Lubricators • Magnesium Alloy Castings

## CANDIDATES

(Continued from page 46)

Boxler, John A., Johnstown, Pa.  
Bradbee, George R., Linden, N. J.  
Brandquist, Robert C., Chicago, Ill.  
Brief, Saul, Brooklyn, N. Y.  
Brodkey, Robert S., Madison, Wis.  
Bruce, Frank Lever, Charlotteville, N. Y.  
Bruce, Warren, Crete Couer, Mo.  
Bryant, John H., New Orleans, La.  
Bucknell, Roger W., Jr., Belleville, Ill.  
Buerkel, William A., Euclid, Ohio  
Burke, William H., Houston, Tex.  
Butler, Thaddeus R., New York, N. Y.  
Carbone, Dominick J., Brooklyn, N. Y.  
Carmichael, Albert S., Jr., Roslyn, N. Y.  
Carvajal, John L., New York, N. Y.  
Cass, Richard S., Newton, Mass.  
Cederberg, George K., Firth, Idaho  
Cetnar, Bernard Walter, Detroit, Mich.  
Chandler, William P., Linden, N. J.  
Chechik, Howard L., New York, N. Y.  
Cheney, John H., Roseville, Mich.  
Child, Edward T., Fairfield, Conn.  
Clarke, David W., Ovid, N. Y.  
Cochrane, George W., Bloomfield, N. J.  
Cochrane, Gordon S., Drexel Hill, Pa.  
Coleman, John S., New Orleans, La.  
Combellick, Wallace A., Gettysburg, S. D.  
Connell, William F., Woodstown, N. J.  
Conner, M. H., Pocatello, Idaho  
Coulman, George, Trenton, Mich.  
Craig, Robert Edward, Philadelphia, Pa.  
Crandell, William H., Worcester, Mass.  
Crell, Jesse, Brooklyn, N. Y.  
Crimi, Fred J., Brooklyn, N. Y.  
Cunningham, Jack W., Pasadena, Tex.  
Cushing, Ralph, Syracuse, N. Y.  
Davies, Thomas E., Joliet, Ill.  
Davis, Richard C., Marion, Ind.  
De Long, Louis F., Bronx, N. Y.  
Diefenbach, R. E., Rye, N. Y.  
Donahue, John F., Jr., Portland, Me.  
Doraiswamy, L. K., New York, N. Y.  
Dumas, Arthur C., Blacksburg, Va.  
Dowler, Warren Leroy, So. Charleston, W. Va.  
Dressel, Oliver D., Sappington, Mo.  
Drummond, John A., Hot Springs, Ark.  
Dumovich, Stanley J., Flushing, N. Y.  
Eber, John A., Newark, N. J.  
Elder, Wm. F., Louisville, Ky.  
Farmer, Thomas S., New Orleans, La.  
Fauver, Vernon A., W. Lafayette, Ind.  
Federman, John L., Indianapolis, Ind.  
Finch, Robert Glenn, Charleston, Ind.  
Fischer, Charles T., Jr., Newport, Ky.  
Flack, William R., Marion, N. C.  
Fleming, Mary F., Syracuse, N. Y.  
Folk, Edwin W., Camden, S. C.  
Forsyth, Robert S., Hollis, N. Y.  
Fountain, Frank S., Norfolk, Va.  
Fried, Albert, Brooklyn, N. Y.  
Fritz, Earle, E. Chicago, Ind.  
Fritz, Jacob Christian, Jr., Baton Rouge, La.  
Funk, William U., Texas City, Tex.  
Gade, Marvin F., Menasha, Wis.  
Garvin, Robert G., Laurel, Miss.  
Gibson, Curtis A., Emporium, Pa.  
Goffinet, Edward P., Jr., Louisville, Ky.  
Gorham, John F., Stamford, Conn.  
Gow, N. Wells, Jr., Glen Ridge, N. J.  
Grammer, Robert E., Elizabeth, N. J.  
Graven, Richard G., Sunnyside, N. Y.  
Greco, Saverio G., Brooklyn, N. Y.  
Groves, Stanford, Midland, Mich.  
Guibert, Robert M., Niagara Falls, N. Y.  
Haffin, William J., Houston, Tex.  
Hagopian, Erivan, Providence, R. I.  
Hanesian, Deran, Niagara Falls, N. Y.

(Continued on page 50)

## DRAIN CORROSIVE WASTES

*Safely, economically*

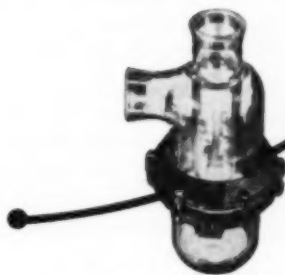
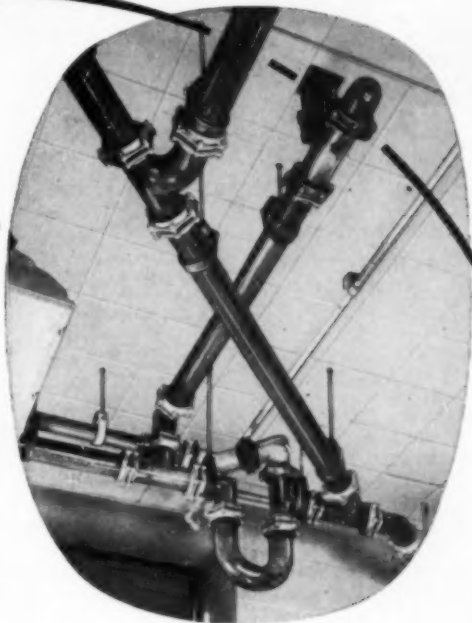
### **PYREX brand "DOUBLE-TOUGH" GLASS PIPE**

Now you can eliminate the costly down time and expensive replacement of corroded waste disposal piping, once and for all, with PYREX brand "Double-Tough" glass pipe. It is exceptionally resistant to all acids, except hydrofluoric, and also withstands the effects of mercury!

PYREX pipe users report phenomenal savings. One large user stated that his entire PYREX pipe installation paid for itself *within nine months*. Another reports: "We have been using PYREX pipelines to dispose of corrosive wastes for nearly three years. We have never had a maintenance problem—never even had to replace a gasket."

Transparency is another advantage. You can keep an eye on drainage. And the ultra-smooth surface of glass practically eliminates the adherence of solids.

What's more PYREX pipe is tough. It is highly resistant to physical and thermal shock. You can drain cold water immediately after hot acids. Available in diameters 1" to 6" with all standard fittings, plus sink traps, odd angle ells and laterals. *Your nearest PYREX pipe distributor can give you complete information. Corning will gladly send you his name on request.*



PYREX brand Sink Traps are non-siphoning and permit easy cleaning. No plug to unscrew. Bulk of water remains in cap. Easily assembled with ordinary wrench.



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*Corning means research in Glass*

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# MEMO from COOPER ALLOY

HAVE YOU  
EVER NOTICED  
HOW TOUCHY  
PEOPLE GET



...as soon as the weatherman turns on the heat? The medicos have a long-winded explanation for it, but it all boils down to the fact that when the heat is on, there's no telling what "hooman beins" are going to do.

That's what we like about metals. If you can read...and if you can understand what you read...and if the metals have read about it too, and understand what they are supposed to do...you can predict just what they will do when the heat is on. We got all this, and a lot more, by reading Norman Mott's discussion on Welding Stainless Alloys. So before you get lost in the day's business, write us for a copy of Norman Mott's paper and watch your I.Q. jump.

You'll learn, for example, that some metals, like some people, have got to be warmed up a bit before you can do anything with them...and that some of them have to be cooled down very gradually after you've had them all hot and bothered.

Fascinating things, these metals!



The **COOPER ALLOY** Foundry Co., Hillside, N.J.

## CANDIDATES

(Continued from page 48)

Marcarufka, John R., Curwensville, Pa.  
Hatfield, Paul E., Springfield, Ohio  
Hauknecht, Charles E., Cleveland, Ohio

Hausmann, Paul L., Washington, Mo.  
Heath, Carl E., Jr., Stateville, N. C.  
Hendrick, Edgar R., Texas City, Tex.  
Hess, Martin, Detroit, Mich.  
Hessler, Norman, Chicago, Ill.  
Hill, Oliver W., Dumas, Tex.  
Hlavin, Vincent F., III, Cleveland, Ohio  
Hofmaier, Herbert H., Philadelphia, Pa.  
Holcomb, Eugene G., Blacksburg, Va.  
Holland, Charles R., Devon, Pa.  
Houston, Neil D., Pittsburgh, Pa.  
Hublein, Harold F., Elmhurst, N. Y.  
Hynds, James P., Jr., Akron, Ohio  
Jackson, Kenneth A., Fresh Meadows, N. Y.

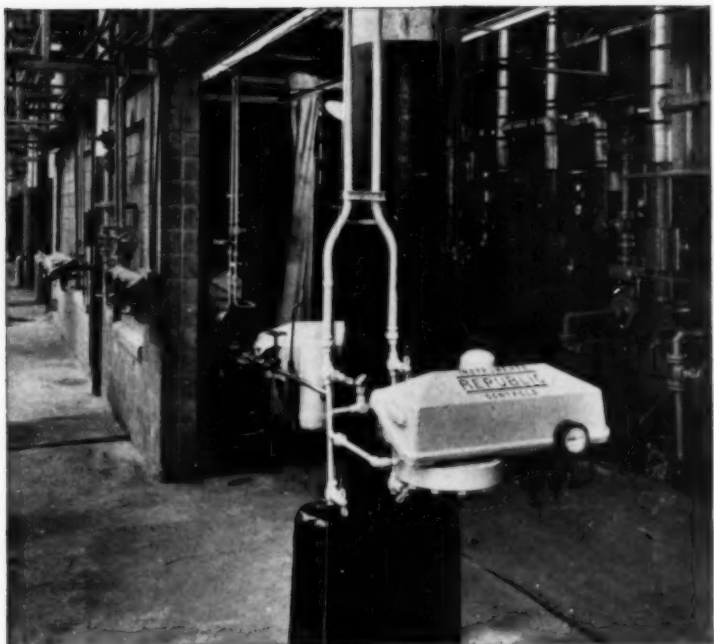
Jagel, Robert C., Upper Montclair, N. J.  
Jakaitis, Eugene A., Philadelphia, Pa.  
Jarvis, Lester C., Farmington, N. C.  
Jeffrey, Dwight, Columbus, Ohio  
Jindrich, R. W., Columbus, Miss.  
Jones, Richard A., Maplewood, N. J.  
Joseph, Elias F., Oak Ridge, Tenn.  
Kadner, Jacob J., Jr., St. Louis, Mo.  
Kaiser, William C., Cleveland, Ohio  
Kemp, Herman E., Jr., Pocatello, Idaho  
Keyes, John J., Jr., Oak Ridge, Tenn.  
King, James J., Jr., Hopewell, Va.  
Kirsch, F. William, Newport, Del.  
Klebanoff, Gregory, Jr., Maspeth, N. Y.  
Koerner, Vance D., Edgerton, Ohio  
Kouba, Norman R., Philadelphia, Pa.  
Kripitzer, Philip, Brooklyn, N. Y.  
Kumar, Prem, Delhi, India  
Kush, Alexander, Trenton, N. J.  
Langley, William D., Sweetwater, Tex.  
Lasser, Howard G., Alexandria, Va.  
Lautensack, Harry, Tonawanda, N. Y.  
Le Clair, Rene M., Charleston, W. Va.  
Lehmacher, William H., Darien, Conn.  
Lester, Herbert C., Jr., Chester, Pa.  
Leventhal, Norman L., Lynn, Mass.  
Lex, Burton Lyle, Hillsboro, Oregon  
Lichtenstadter, Manfred, Brooklyn, N. Y.

Lloyd, Julius E., Cos Cob, Conn.  
Lohrenz, John, Baton Rouge, La.  
Longo, Joseph, Jr., E. Boston, Mass.  
Lortscher, Lawrence L., Columbus, Ohio  
Maak, Robert O., New York, N. Y.  
Mac Connell, John D., Philadelphia, Pa.  
Mahne, Frank, Euclid, Ohio  
Mallatratt, Alvin S., Allentown, Pa.  
Maravell, Charles N., Louisville, Ky.  
Marcell, Richard L., Palisades Park, N. J.  
Markas, Stephen E., Pittsburgh, Pa.  
Marocco, Bernard P., Tuckahoe, N. Y.  
Martzoff, J. A., Fullerton, Calif.  
Marvin, Earl J., Niagara Falls, N. Y.  
Matesky, Thomas, Syracuse, N. Y.  
Mathews, William J., Jr., Bound Brook, N. J.

Matoi, H. James, Fontana, Calif.  
May, Irene DuP., Wilmington, Del.  
McCarthy, Joseph Alfred, Cleveland Heights, Ohio  
McGillicuddy, Robert P., Aberdeen, Wash.  
McIntyre, John F., Jr., Washington, Mo.  
McNeil, R. R., Detroit, Mich.  
Mead, Gordon F., West Cheshire, Conn.  
Meinhardt, Alfred J., Jr., Clifton, N. J.  
Miller, Everett J., Bloomfield, N. J.  
Milne, Kevin C., Calgary, Alta., Canada  
Miskell, Ford F., Wauwatosa, Wis.  
Mixon, F. Orion, Jr., Murfreesboro, N. C.

Mladinich, John L., New York, N. Y.

(Continued on page 52)



## **These Meters Had To Be ACCURATE — FLEXIBLE — RUGGED**

**One hundred twenty one** Republic Pneumatic Transmitters are measuring the flow and level of various acids in a large chemical processing plant, a section of which is pictured above.

These transmitters have a guaranteed accuracy of within  $\frac{1}{4}$  of 1% of the transmitter range. By making a few minor adjustments or substituting a few small parts, their operation can be easily changed to any desired range between a minimum of 0—0.6" of water to a maximum of 0—704" of water. Their construction is more like that of a precision machine than of the sensitive instrument they are. It is for these reasons that Republic Pneumatic Transmitters, even though comparatively new, have already

been specified and installed on over 2500 industrial metering applications.

Republic Pneumatic Transmitters are available for measuring flow, liquid level, pressure or liquid density of a wide range of fluids. They employ the force-balance principle to convert these process variables into air pressures which vary proportionally. These air pressures become direct measurements and can be conducted to reading instruments or used as the measuring impulse for the actuation of an automatic controller.

Data Book No. 1001 contains complete details on the construction and operation of Republic Transmitters. Write for your copy today.

**REPUBLIC FLOW METERS CO.**

2240 Diversey Parkway, Chicago 47, Illinois



*There is a*  
**PYROFLEX CONSTRUCTED TANK**  
*for*  
**EVERY CORROSIVE SOLUTION**



Two courses of acid proof brick set in Knight acid proof cement are installed over Pyroflex lining in pickling tank.

Every Pyroflex-Constructed Tank is individually engineered to do a specific job. For example, the pickling tank above must handle a hot sulphuric acid solution. A steel shell was lined with a heat-bonded Pyroflex sheet membrane. Two courses of acid-proof brick set in Knight No. 2 Acid-Proof Cement were installed. Exterior surfaces were covered with Pyroflex. The result is a tank completely resistant inside and out to the corrosive conditions under which it must function.

Tanks for pickling stainless must handle nitric and hydrofluoric acid. Suitably constructed tanks are also built for this service. Pyroflex Construction is not limited to the use of any particular materials. Each unit is constructed of whatever materials best meet individual requirements. Thus, you are assured of a tank tailor made to fit your job—to give long trouble-free service with less maintenance and down time. Pyroflex-Constructed Tanks can be shipped F.O.B. Akron, or lined on the job site by skilled field crews.

Write for Bulletin No. 2F, Pyroflex Construction.

**Maurice A. Knight** 708 Kelly Ave., Akron, Ohio  
**Acid and Alkali-proof Chemical Equipment**

## CANDIDATES

(Continued from page 50)

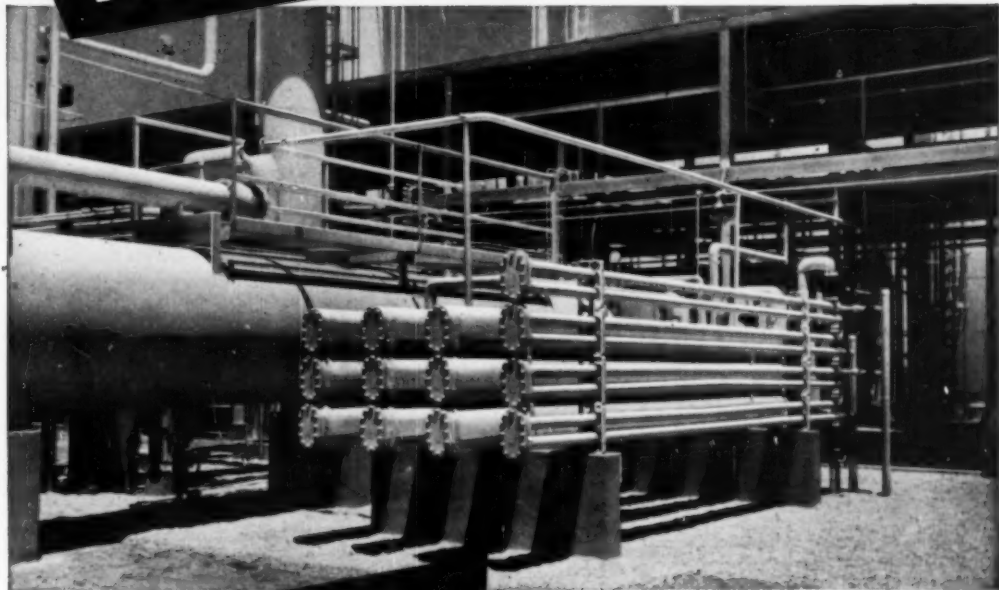
Mohr, Richard A., Plainfield, N. J.  
 Mohrmann, Fred R., West Haven, Conn.  
 Montgomery, William Jackson, Texas City, Tex.  
 Moore, Marlin C., Niagara Falls, N. Y.  
 Mraz, Paul Joseph, Cleveland, Ohio  
 Munion, James H., Philadelphia, Pa.  
 Nabors, Jack D., Carlsbad, N. M.  
 Nachbar, Milton S., Brooklyn, N. Y.  
 Natkin, Alvin M., Brooklyn, N. Y.  
 Naugler, Earl, Brewer, Me.  
 Nechvatal, Stanley R., Cleveland, Ohio  
 Neuman, John Andrew, Chicago, Ill.  
 Neunhoffer, Charles N., Cambridge, Mass.  
 Noll, Raymond F., Avon Lake, Ohio  
 Norton, John Robert, Hoxsie, R. I.  
 Odle, William, Charleston, W. Va.  
 Olandt, Robert H., Bloomfield, N. J.  
 Orstadt, Alan J., Fort Wayne, Ind.  
 Osment, Harry E., Birmingham, Ala.  
 Painter, John Boyd, Flemington, N. J.  
 Painter, Louis J., Philadelphia, Pa.  
 Palumbo, Richard R., Akron, Ohio  
 Parker, Richard H., Pulaski, N. Y.  
 Peck, Clyde G., Cleveland Heights, Ohio  
 Pendleton, Elmer L., Columbus, Ohio  
 Perkins, Thomas K., Dallas, Tex.  
 Pettit, J. Phillips, Cincinnati, Ohio  
 Phillips, Martin A., Jr., Cleveland, Ohio  
 Phinney, C. M., Jr., Larned, Kan.  
 Pierce, Gerald E., Lake Jackson, Tex.  
 Piser, John W., Mineola, N. Y.  
 Plowright, John D., Wilmington, Del.  
 Post, Vincent H., Pottsville, Pa.  
 Prescott, George R., Charleston, W. Va.  
 Pritchard, B. L., Jr., Clovis, N. M.  
 Raynes, Mitchell, Augusta, Ga.  
 Redgrift, Harry F., Boston, Mass.  
 Reimer, Donald W., Cactus, Tex.  
 Reitman, Paul, Brooklyn, N. Y.  
 Richter, Tellmond H., Jr., Clarkwood, Tex.  
 Rinald, Donald, Wood-Ridge, N. J.  
 Rivas, Fred Blake, Nixon, N. J.  
 Roberts, John R., Drexel Hill, Pa.  
 Robinson, Richard I., Corsicana, Tex.  
 Robinson, S. Bernard, Fort Wayne, Ind.  
 Roe, Burton J., Haddon Heights, N. J.  
 Rogak, Earl D., Brooklyn, N. Y.  
 Rose, Vincent C., Jr., Tiverton, R. I.  
 Ross, Edward F., Cuyahoga Falls, Ohio  
 Ross, Kenneth R., Newton Falls, N. Y.  
 Rounsley, Robert, Detroit, Mich.  
 Rumsey, David S., Charleston, W. Va.  
 Russell, R. LeMar, Birmingham, Ala.  
 Sanders, Vernon R., Aurora, Col.  
 Saylor, Richard E., Niles, Ohio  
 Schmitz, Charles J., New York, N. Y.  
 Schoepfer, Arthur E., Chicago, Ill.  
 Schora, Frank C., Jr., Providence, R. I.  
 Schrock, Donald B., Avon Lake, Ohio  
 Selbe, Rexford L., Evanston, Ill.  
 Sharangpani, R. M., New York, N. Y.  
 Shayer, Lawrence D., Brooklyn, N. Y.  
 Shoch, Clarence T., Jr., Louisville, Ky.  
 Shroff, Phiroze D., Pittsfield, Mass.  
 Siegel, Howard M., Brooklyn, N. Y.  
 Sievering, Philip J., Jr., Maplewood, N. J.  
 Silberzweig, Harold, Brooklyn, N. Y.  
 Singley, Lynn W., Charleston, W. Va.  
 Siwaslian, George, Elmhurst, N. Y.  
 Sleik, Harold, Bronx, N. Y.  
 Slusser, Robert P., So. Charleston, W. Va.  
 Smith, Howard, Brooklyn, N. Y.  
 Smith, John R., Euclid, Ohio

(Continued on page 61)



**Assure  
Flexibility**

**in your plant**



with  
**BROWN  
FINTUBE**

**sectional hairpin  
heat exchangers**

● You'll get almost unlimited flexibility to meet changes in duties, plant re-arrangements, etc., with Brown Fintube Sectional Heat Exchangers. By simply adding a few sections to your existing exchangers, or removing a few sections, or changing the series-parallel manifolding, change-overs can be made easily and quickly. You can be operating efficiently on almost any new or different duty, on short notice, with a minimum of expense for new equipment, and without obsoleting any of your former facilities.

For utmost efficiency and economy use Brown Fintube Sectional Heat Exchangers throughout your plant. Write for Bulletin No. 512.

**THE BROWN FINTUBE CO.**

*Elyria, Ohio*

Sectional Hairpin Heat Exchangers  
Tank Section and Line Heaters  
Fintube Heaters for Bulk Storage Tanks  
Indirect Process Air Heaters  
Fintube Heaters for Processing Tanks  
Integrally Welded Fintubes for Any Heating,  
Cooling or Heat Transfer Service

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## MARGINAL NOTES

(Continued from page 42)

sufficiently clear to exclude the possibility of misunderstanding. There are substantial errors, as on page 35 where it is stated that a patent may contain "one generic claim and also claims to two species of the invention." There, of course, may be more than one generic claim in any patent, and for many years claims to three species were allowed. Currently the Patent Office allows a patent to contain claims to five species in addition to generic claims.

While the photographs add little to the understanding of the text, the author uses charts and check lists helpfully. However, the final check list contains a puzzling statement in which the author says that, after filing, the patent application should always be sent by registered mail with a cover letter. But he is entirely silent as to why and to whom a filed application should have to be sent, by registered mail or otherwise. Another peculiar statement is that infringement suits are "usually" brought in the Federal Courts. At one time, this may have been an open question, but it seems clear now that the Federal Courts have exclusive jurisdiction.

The author mentions foreign patents, but does not describe the difficult problems peculiar to them.

The booklet has many virtues, the chief one being that it is the only publication of this much-needed, condensed type.

**Cathodic Protection. A Report of the Correlating Committee on Cathodic Protection. National Association of Corrosion Engineers, Houston 2, Tex. (1951) 33 pp. 50 cents a copy.**

Reviewed by R. B. Mears, Mgr. Research and Development Lab., U. S. Steel Co., Pittsburgh, Pa.

**T**HIS booklet was prepared by a committee sponsored by ten national industrial organizations and an engineering association. Its purpose is to disseminate information on the use of cathodic protection to reduce destruction of underground structures by corrosion. The booklet is made up of four bulletins and a foreword. The foreword points out that underground corrosion is costing American industry about a billion dollars annually and that much of this economic loss can be prevented by the proper application of cathodic protection.

One part is directed toward management or general-interest readers. It describes in general terms the causes of underground corrosion and the various means of preventing or reducing it. Advantages of cathodic protection are

stressed. It is emphasized, however, that installation of cathodic protection should generally be a cooperative effort and that any operator planning a cathodic protection installation should notify operators of neighboring buried structures so that interaction problems can be appraised.

Cathodic protection notification procedures are covered in more detail and suggestions are made that committees be formed in urban areas to assist in the correlation of cathodic protection notification and survey problems.

Fundamentals of the application of cathodic protection and the mitigation of any electrolytic corrosion, caused by stray currents from cathodic protective systems, are discussed. Technical practices now in use for determining how much protective current is required are described and information is given on the location and spacing of current supply points. Relative merits of external power sources are compared with those of various types of galvanic anodes. A bibliography on cathodic protection, containing 56 references, is attached to this Bulletin.

Joint cathodic protection systems are described. Techniques for the design and installation of such joint systems, possible divisions of responsibility for their construction, operation and maintenance, and the sharing of costs are all discussed. Also, an outline of the principal points that may be included in any agreement between the owners of the various structures, is presented.

This booklet fills a definite need. Copies of it should be available to the supervisory and engineering personnel of all pipe-line companies, water and gas companies, electric power, telephone and telegraph companies. It is to such people that the booklet is primarily directed. In addition, the electrical engineering staffs and maintenance engineers in the metallurgical and chemical industries should also become familiar with this booklet. In the plants of such industries there are frequently many miles of underground structures that would benefit by being cathodically protected. This booklet serves as an excellent introduction to the subject of cathodic protection of the underground structures in such mills.

### A Best Seller for Better Living

**The Story of the Rockefeller Foundation. Raymond B. Fosdick. Harper and Brothers, New York. (1952) 336 pp. \$4.50.**

Reviewed by W. W. Niven, Jr., Chmn., Chem. Eng. Div., Midwest Research Institute, Kansas City, Mo.

**T**HIS book presents an informative narration of the trials, tribulations and successes encountered in the forma-

tion and operation of one of the first great private organizations devoted to "betterment of world-wide human welfare." It is hard for us to understand today that any benefactor having millions of dollars to offer "with no strings attached" should meet strong resistance. Yet, all too often, such was the situation facing the Rockefeller Foundation, even from the Congress of the United States.

Mr. Fosdick, through his long association with the Foundation, for twelve years as president, is eminently qualified to tell this story, and does so in a highly readable and interesting manner. One "fault" lies in the fact that, in an extensive recognition of those who contributed to the success of the Foundation, he scarcely mentions his own part.

To quote Mr. Fosdick, "This book is primarily for laymen . . . . The range of the activities of the Rockefeller Foundation is so vast and covers so many fields that any description prepared for specialists would have to be prepared by a group . . . . The vastness of this range is attested by the profound parts played by the Institute in public health, medicine, medical education, agriculture, social sciences and the humanities.

The chemical engineer should not expect in this book to find answers to his immediate professional problems. As a common participant in the strivings of the human race towards a better life, he will learn much about the demonstrated accomplishments that are possible from the important combination: A plan and a means.

### A Story Called Aluminum

**ALCOA An American Enterprise. Charles C. Carr. Rinehart & Co., Inc., New York (1952) 292 pp. \$3.50.**

**E**VERY evening this reviewer gazes from the top of a Riverside Drive bus across the Hudson River to the Jersey Palisades and spots the word ALCOA in red lights and in green underneath the appositional—Aluminum Company of America. Nothing more, just a product, just a corporation. Or so it seemed until Charles Carr, publicity representative of the above-mentioned company for 15 years, produced a readable book of a great American undertaking. This history will not only interest the metallurgist, and those who have business with metals, but also the man who finds inspiration and encouragement in an account of the pioneering work and vicissitudes which a company endures in passing from a small venture to a great enterprise.

And a gigantic enterprise this can be termed, judging by its war record alone. The only published record of wartime

(Continued on page 56)

# MORE PRODUCTS FROM NATURAL GAS

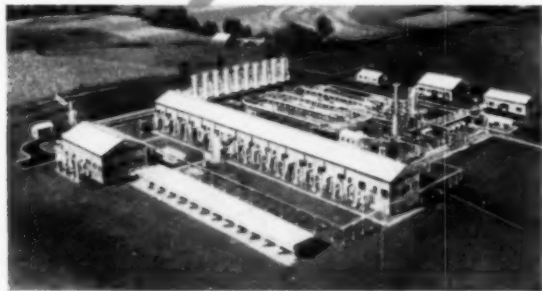


*Matheson Chemical Corporation Plant  
Doe Run, Kentucky*

From Gabe, Kentucky, liquid hydrocarbons extracted from natural gas are piped to Doe Run. Here, at the rate of 450,000 gallons per day, they are converted into domestic bottled gas, natural gasoline, and "permanent" anti-freeze, as well as intermediates for the manufacture of plastics and synthetic fibres.

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*Hydrocarbon Extraction Plant  
Tennessee Gas Transmission Company, Gabe, Kentucky*

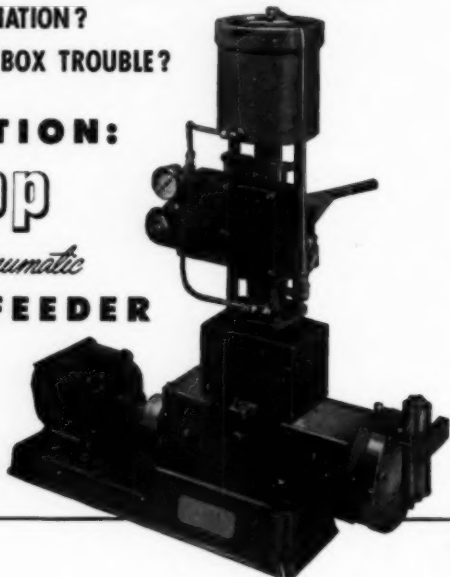


## PROBLEM:

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POSITIVE, AUTOMATICALLY-REGULATED FEED?  
CONTAMINATION?  
STUFFING BOX TROUBLE?

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Chemicals successfully being handled include gum and sludge inhibitors, metal deactivators, anti-oxidants, dyes and stabilizers. Also those for boiler water or processing water treatment—concentrated sulphuric acid, sodium sulphite, filter aid slurries, liquid caustic. For the Lapp Pulsafeeder is the positive-displacement pump for controlled-volume pumping of liquids which depends on no stuffing box or running seal—avoids contamination by an hydraulically-balanced diaphragm which isolates pumping mechanism from chemical being handled. Pumps against pressures up to 2,000 lbs., at constant pumping speed—variable flow results from variation only in piston-stroke length. Auto-Pneumatic control uses instrument air pressure responding to any instrument-measurable variable.

**GOT A SPECIAL PROBLEM?** Every month we hear about applications to which the Lapp Pulsafeeder is the long-awaited answer. A newly-issued bulletin, No. 300, will tell you about our pump and its characteristics, with typical applications and flow charts. A Pulsafeeder Inquiry Data Sheet, on which you can outline your processing requirement, will bring an engineering recommendation. Write us today. Lapp Insulator Co., Inc., Process Equipment Division, 538 Maple Street, Le Roy, N. Y.

**Lapp**

*Auto-Pneumatic*

**PULSAFEEDER**

## MARGINAL NOTES

(Continued from page 54)

performance over Alcoa signature was a "Timetable of Aluminum for Victory," issued in the spring of 1943. The figure of \$250,000,000 mentioned in the Timetable as the amount of Alcoa's own money or credit invested in expansions became \$300,000,000 by V-J Day. In addition to this, the company built for the government, without fee or profit, aluminum plants representing an investment in excess of \$450,000,000. Into these accomplishments went the brains and brawn of thousands of men who inherited some of the verve and courage of the progenitors of this venture—men who before the turn of the century had gotten hold of an idea and had carried it through to fruition.

It was Charles Martin Hall, a twenty-two-year-old American, who succeeded in his search for an economical method and commercially useful process of making aluminum. The Hall process is essentially the commercial process currently in use though the author refers to the continuing efforts of the company to add improvements in accordance with today's requirements. In eulogizing the work of Hall, full credit is given also by the author to Oersted, the Danish scientist, who sixty years before Hall (1826) produced metallic aluminum from its compounds.

In Mr. Carr's moving tale of Alcoa's growth and development are stories within his main one, namely that of water power, patents, the struggle for early markets, beginnings of industrial research, the Federal Trade Investigation, Labor Relations, World War I as it affected Alcoa and the contrast of the demands on Alcoa during World War II.

As supplementary information the author gives a chronological record of Alcoa's Labor Negotiations 1935-50. He also includes an index of names and subjects. Alcoa is not just a popular name in lights—in Mr. Carr's appraisal it is a significant industry in war and in peace.

—H.R.G.

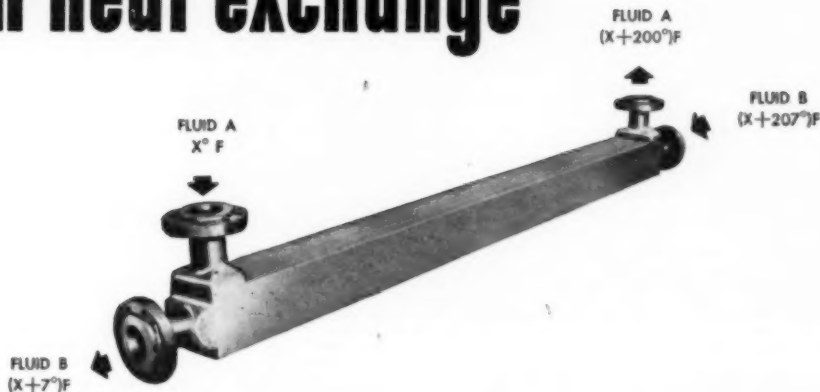
### Books Received

**Technical Publications 1949.** 4th vol. Arman E. Becker, editor. Standard Oil Company (New Jersey) (1951) 551 pp.

Twenty-four articles are reprinted in this fourth volume of Technical Publications, together with the list of other papers, published in technical journals during 1949 by members of Standard Oil Company (New Jersey) and affiliated companies.

**The Phosphatides.** Harold Wittcoff. Reinhold Publishing Corp., New York. (1951) 564 pp. \$10.00.

# Now... closer temperature approaches in heat exchange



## WITH **TRANE** BRAZED ALUMINUM SURFACE

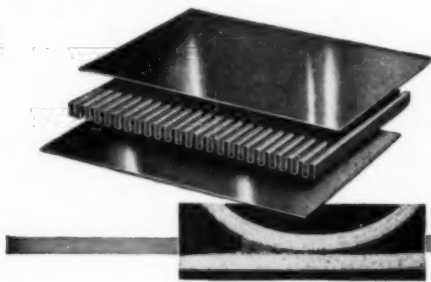
Now . . . even with a large temperature change or drop . . . you can obtain *temperature approaches of 5° to 10° F.*

TRANE Brazed Aluminum heat exchange surface makes it not only possible—but *practical!* That's because the new TRANE Brazed Aluminum packs up to 450 square feet of surface into a single cubic foot of space.

This huge amount of surface in a single unit makes maximum use of available pressure drop. And you don't lose pressure through connections.

TRANE Brazed Aluminum can handle heat transfer between three, four, five or more streams simultaneously—liquid to liquid, liquid to gas, or gas to gas. Temperatures from 500° F. to -300° F. Tested at pressures up to 1000 Psig.

*Want more information? Contact your nearest TRANE sales office, or write The TRANE Company, LaCrosse, Wis.*



**WHAT IS BRAZED ALUMINUM?** A stack of flat plates and corrugated fins in layers, all brazed in perfect bond. Strong, light, compact and completely flexible. Illustration below shows strong fillet formed between fin and plate.

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# SPONSORSHIP OF ADVANCED STUDY COURSES IN CHEMICAL ENGINEERING

M. C. THRODAHL, R. VOORHEES, and A. G. DRAEGER

Charleston (W. Va.) Section

THE Professional Guidance Committee of the Institute has for some time been promoting activities among the local sections aimed at improving the sense of professional status and responsibility, especially among the younger members of the Institute. Many employers have been aware that a number of chemical engineers who seem to show unusual promise upon graduation from college, pass through a definite slack period a few years after leaving school. It has been observed that some of these men feel they are not making satisfactory progress either from the point of view of professional development or with respect to advancement within their organization. One of several projects the Committee has undertaken, in efforts to alleviate this situation, is a program of refresher courses in chemical engineering principles, as well as advanced training of a similar nature. By formalizing this program of study into definite classes meeting at regular times some measure of progress can be made among the participants of such courses.

Inauguration of the study program sponsored by the Charleston Section began as a result of discussions between D. O. Myatt, chairman of this project subcommittee of the Professional Guidance Committee, and representatives of the Charleston Section during the White Sulphur Springs meeting in March, 1951. R. Voorhees was appointed to the Professional Guidance Project Subcommittee to improve liaison between the local and national groups. The Charleston representatives were confident that such a program could be organized and operated, and pointed to the success of a somewhat similar program which flourished in the Charleston area during the years just prior to World War II. (The Charleston Section of the Institute was not organized at that time and the study program was operated by an

## EDITOR'S NOTE

The Institute's sponsorship of projects for improving the profession has yielded some interesting results at the local level. Three one-day "Teach the Teacher" schools, held at chemical engineering plants for chemical engineering faculty members, were the outcome of a project initiated three years ago by the Chemical Engineering Education Projects Committee (1, 4). Activities of the New York Section in counseling and stimulating chemical engineering students and young graduates were recently reported (5). A New Jersey Section lecture series, independently initiated about two years ago, was most successful (3). The story on A.I.Ch.E. committee activities was started in 1951 (2).

organization known as the Charleston Junior Engineers Association. The CJEA was formed in 1938 and operated until about 1942, when it was forced to disband because of the press of war activities.)

The approximately one hundred members of the CJEA organized and conducted about four study courses simultaneously. Each course met for one evening every alternate week and lasted from four to eight months. With few exceptions there were no regular instructors, most of the groups being self-taught through the procedure of having the material assigned in rotation to different members of the class who would then familiarize themselves with it and report back to the class at some later date. Two of these classes were in the form of group correspondence classes wherein material for the course was furnished by a university offering this type of program. Most of the courses offered during this period were techni-

cal in nature, comprising subjects such as advanced distillation, organic chemistry, corporation finance, industrial relations, etc.

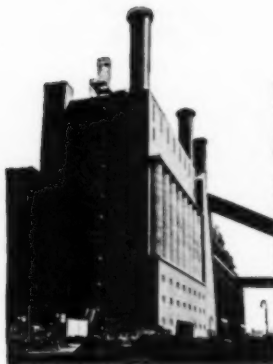
**Unit Operations Committee.** The suggestion that the Charleston Section sponsor some sort of program was taken up with the Executive Committee of this Section in the spring of 1951 and met an enthusiastic response. A Unit Operations Committee was appointed, composed of the following junior members of the Institute: A. G. Draeger, Westvaco; H. S. Edwards, Jr., Carbide; A. A. Gruher, DuPont; D. E. Hildebrandt, DuPont; W. R. Manning, Carbide; R. J. Sollenberger, Carbide; and M. C. Throdahl, Monsanto, chairman. The Committee's first task was to survey the junior membership of the Section to determine whether there was interest in a study course program.

**Organization and Operation of Courses.** On the basis of this survey among the Junior members of the Institute in May, 1951, the Unit Operations Committee proceeded with the organization and supervision of two courses beginning in October, 1951, and continuing through to June, 1952. The initial survey was limited to the classical unit operations only. Those unit operations receiving greatest preference in this survey were as follows: Distillation, Heat Transfer, Fluid Flow, and Absorption.

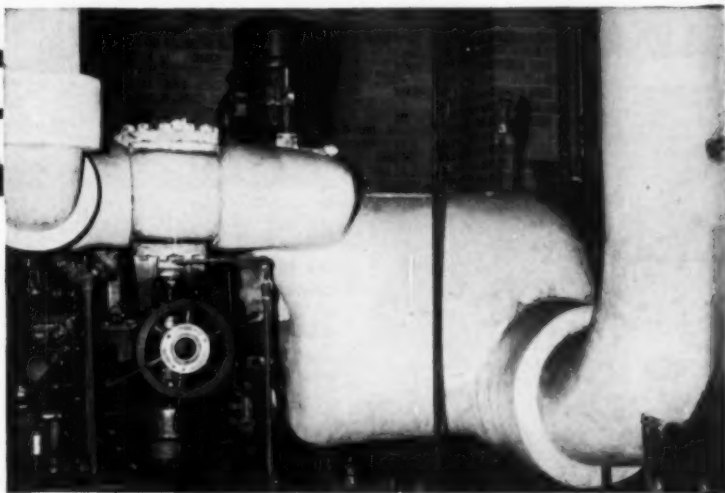
The response to the first course in Advanced Distillation was far greater than expected and it was necessary to limit the enrollment to 148 persons, the capacity of the available lecture room. More than fifty advanced enrollment fees were returned because of lack of seating space.

As a result of the survey the Committee designed a curriculum for each

(Continued on page 63)



**For this new addition to their New York City power plant at East River and 14th Street...**



(Above) View of recently completed annex to Consolidated Edison's power plant... another link in their gigantic expansion program. (Right) Close-up of J-M 85% Magnesia Insulation on boiler feed lines. It was expertly installed by the Asbestos Construction Company, Inc., an outstanding J-M Insulation Contractor.

## CON EDISON SPECIFIES J-M 85% MAGNESIA PIPE INSULATION FOR MAXIMUM FUEL SAVINGS

Like all materials that went into the new power plant addition of New York's leading gas and electric supplier... the pipe insulation had to be the best. That's why Consolidated Edison Co. specified J-M 85% Magnesia... industry's No. 1 insulation for many decades and still the leader in its class.

J-M 85% Magnesia is the leading insulation on the market for temperatures up to 600°F. It is bonded with asbestos fibers. This rugged insulation will not distort regardless of the length of time it stays in service. J-M 85% Magnesia fits snug and stays put. Heat savings, therefore, remain constant for the life of the equipment on which this insulation is applied.

For temperatures over 600°F, J-M 85% Magnesia is used in combination with Superex\*, a J-M insulation for service to 1900°F. This double-layer construction, known as Superex Combination, eliminates through joints and protects the jacket against scorching. It also utilizes the higher

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heat resistance of Superex next to the hot surface, and the greater insulating value of J-M 85% Magnesia for the outer layer.

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When you face your next insulating problem... remember that Johns-Manville is "Insulation Headquarters." Consult your near-by J-M Insulation Contractor... or write direct to Johns-Manville, Box 60, New York 16, New York. In Canada, write 199 Bay Street, Toronto 1, Ontario.

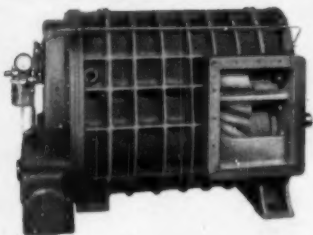


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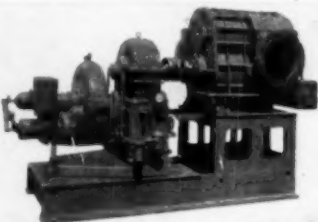
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To meet the specific needs for industry, Standardaire's unique design provides for maximum flexibility in meeting unusual requirements for intake and discharge connections. For example, the blower intake or discharge ports can be located on the end, top, bottom or sides—two intake or discharge ports may also be provided when necessary. These exclusive features, plus provisions for direct drive by a power unit of your choice, are typical examples of Standardaire's adaptability.



Standardaire Blower with single top intake and two side discharge ports.



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## SECRETARY'S REPORT

(Continued from page 44)

Upon recommendation of the Local Sections Committee, Council voted to authorize the establishment as a local section of the Institute the group known as the Nashville Society of Chemical Engineers. The section shall be called the Nashville Section of the Institute.

In an effort to determine the interest of the membership in the publication of a Cumulative Index to the Transactions of the Institute, Volumes 1-42, a notice has been mailed with the Chicago Meeting Program. If published, this Index would not exceed \$10.00 per copy.

The Council reviewed the financial status of the Student Chapter News and its prospects for the school year 1952-1953, after which it was decided to continue the publication of the Student Chapter News and to retain J. G. Knudsen as Editor.

The report of the Chemical Engineering Education and Accrediting Committee was received and the recommendations of the Committee to act favorably on twenty-three chemical engineering curricula were approved.

### Nominees for Directors 1953-1955 Suggested by Local Sections

Local sections have suggested the following as possible nominees for Directors for three years in accordance with practice established a few years ago:

Section	Nominee
Baton Rouge—	L. B. Smith
Boston—	A. W. Fisher, Jr.
Central Ohio—	Frank C. Croxton
Chicago—	W. L. Faith
Cleveland—	Curry E. Ford
Columbia Valley—	Lee Van Horn
Detroit—	D. L. Katz
Kansas City—	C. W. Nofsinger
Maryland—	Melvin C. Molstad
New Jersey—	Eger V. Murphree
New York—	L. P. Scoville
Northern California—	Lee Van Horn
Ohio Valley—	Proctor Thompson
Oklahoma—	G. G. Oberfell
Philadelphia-Wilmington—	W. T. Dixon
Pittsburgh—	Carl C. Monrad
Rochester—	John L. Patterson
Southern California—	Lee Van Horn
South Texas—	Ralph H. Price
Terre Haute—	R. Norris Shreve
Texas Panhandle—	G. G. Oberfell
Tulsa—	I. A. Anson
Twin City—	Jose B. Calva
Washington-Oregon—	Lee Van Horn
Western Massachusetts—	Allan W. Low
Western New York—	C. C. Coakley

Of the sections not listed six have indicated that they will not make a nomination this year and no reply has been received from eight sections. The original notice requesting nominee suggestions was sent out March 6; on May 8 a second letter was sent to those from whom we had not heard, and a third letter was sent May 29. It can now be assumed that the list of local section nominees as shown here is complete.

## CANDIDATES

(Continued from page 52)

Smith, William Tulley, Washington, D. C.  
Smura, B. Bernard, Solway, N. Y.  
Snyder, Milton, Brooklyn, N. Y.  
Soehlke, Richard George, Alton, Ill.  
Spalding, Joseph M., Louisville, Ky.  
Spinelli, Filbert E., McKeesport, Pa.  
Stern, Herman A., Lancaster, Pa.  
Stimpff, Richard J., Hempstead, N. Y.  
Stolton, Stephen J., Milwaukee, Wis.  
Struber, Victor R., Brooklyn, N. Y.  
Sullivan William J., Schenectady, N. Y.  
Taylor, Gordon J., Cleveland, Ohio  
Thomaides, Lazarus, Jersey City, N. J.  
Thorne, Henry C., Jr., Ithaca, N. Y.  
Vaughn, William A., Nitro, W. Va.  
VanHoozer, John, Windsor, Mo.  
Vogt, Harvey J., Columbus, Ohio  
Wagner, William F., Louisville, Ky.  
Walden, Philip A., Fremont, Ohio  
Walters, Frederick W., Brooklyn, N. Y.  
Walters, William H., Wilkes-Barre, Pa.  
Wareham, L. D., Houston, Tex.  
Weissman, Irving H., Houston, Tex.  
Whitney, Philip G., Montclair, N. J.  
Wistrich, Harry A., Walnut Creek, Calif.  
Woelfel, Frank R., So. Osage Park, N. Y.  
Wolfberg, Leonard H., Joliet, Ill.  
Wooten, Perry R., Alton, Ill.  
Worthylake, Chester A., Jr., Augusta, Me.  
Wyatt, Edward S., Brazil, Ind.  
Yust, Charles S., Newark, N. J.  
Zurl, Aloysius J., Woodhaven, N. Y.

## NEWS

(Continued from page 40)

### FLUID TURBULENCE OCCURS NATURALLY

A basic problem in fluid turbulence was recently solved at Columbia University. The mathematical solution has baffled engineers and physicists since 1888, when the English scientist William Thomson Kelvin started speculation on it.

Announcement of the solution was made by Prof. Wallace J. Eckert, director of the Watson Scientific Computing Laboratory at Columbia. The work was done under the direction of Dr. L. H. Thomas, professor of physics on the staff at the Laboratory using International Business Machines' Selective Sequence Electronic Calculator. The electronic "brain" telescoped 100 years of hand computation into 150 hr. of machine-operating time, performing some 20,000,000 calculations in the process.

The controversy just settled concerned the origin of turbulence in a stream of fluid flowing at uniform speed between two parallel plates. A hypothetical example of this situation would be a curtain of water falling between parallel sheets of glass at constant speed.

Kelvin and many present-day theorists in the science of hydrodynamics have been convinced that some finite,

(Continued on page 62)

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*utilizing radioactivity, will do this and many other measurement feats you may have thought virtually impossible! At the Cleveland instrument show you will be able to see it work—learn how it performs gas analysis, indicates interface liquid level measurements, measures surface films without contact with the material being measured—and with unheard-of simplicity, amazing accuracy!*

**SOMETHING NEW HAS BEEN ADDED TO THE SCIENCE OF MEASUREMENT—PLAN TO SEE IT AT BOOTH 616—SEVENTH NATIONAL INSTRUMENT EXHIBIT, CLEVELAND—SEPTEMBER 8 THROUGH 12.**

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Capacity from  
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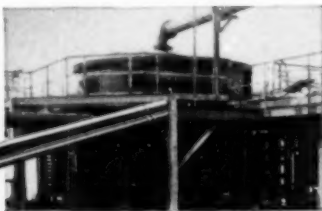
**ACID-PROOF TANTALUM**

## Heat Transfer Equipment

"One of our problems was to add more capacity to sulphuric acid concentrator equipment. Even if we had space for them, it would take months to build more concentrators. By installing tantalum bayonet heaters and using higher steam pressures, we got the desired additional output. In some cases, concentrator capacity was increased 300 per cent."

### TANTALUM BAYONET HEATER

used in Simonson-Mantius concentrator for  $H_2SO_4$  recovery. More than 250 bayonet heaters have been made for this use. The first, installed in 1945, is still in service.



**USE TANTALUM WITH ECONOMY** for most acid solutions, corrosive gases or vapors; not with HF, alkalis, or substances containing free  $SO_3$ .



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**Fansteel Metallurgical Corporation** NORTH CHICAGO, ILLINOIS, U.S.A.

Ewing Galloway

## FLUID TURBULENCE

(Continued from page 61)

outside disturbance would have to be introduced into the "plane Poiseuille flow" just described to break up its regular motion. The Columbia-IBM finding proves, however, that fluids of low viscosity when moving rapidly become unstable without any outside influence. The solution of the elementary problem of instability in a plane Poiseuille flow may prove of value in laying the groundwork for a comprehensive theory of turbulence in general.

A numerical attempt of the problem just solved was suggested four years ago by Dr. John von Neumann of the Institute for Advanced Study at Princeton, N. J. A limited number of cases were solved mathematically on IBM's calculator at that time but these were not for sufficiently rapid flow to settle the controversy conclusively.

The latest attack was launched by Dr. Thomas who worked out a method of solving for the complex "eigen-values" of the Orr-Sommerfeld differential equation—determinations which solved the long-standing controversy. The equations were adapted to the giant calculator by Phyllis K. Brown and Donald A. Quarles, Jr., of IBM's pure science department.

Discussing the implications of the work, Professor Thomas said:

This settles one point of a very difficult problem. There is no accepted theory of turbulent motion and how it sets in, though much empirical data exist. The difficulty is that theorists haven't been able to push beyond the data with certainty—they are not sure what would happen in some of the simplest cases of fluid flow. To work these out without computation requires very troublesome mathematical analysis. Until the advent of machines like the IBM SSEC we were incapable of handling such complex problems by direct computing.

Our results have fortunately settled some current arguments in hydrodynamics—specifically they support the work of Prof. C. C. Lin of the Massachusetts Institute of Technology who was able to arrive at some similar results by using asymptotic formulas.

It is our hope that solving this problem in hydrodynamics will open up the way to dealing with other relatively simple problems which also have resisted solution. Naturally, we hope results of this kind will help in the task of obtaining a good theory of turbulent motion.

## HIGH PRESSURE SYMPOSIUM

(Continued from page 27)

**Design and Application of Controlled Volume Pumps for High Pressures**—Donald H. Jones, mechanical engineer, Milton Roy Co.

**Seals to Minimize Leakage at Higher Pressures**—B. A. Niemeyer, Experiment Inc.

**A Static-Dynamic Load Machine for High Pressure**—E. T. Fleischhauer and E. G. Dorsey, Jr., Experiment Inc.



## CHARLESTON COURSES

(Continued from page 58)

of the courses on the basis of three-hour sessions held alternate weeks. During the summer of 1951, the Distillation curriculum was planned, the lecturers contacted, and the lecture hall procured. Heat Transfer course arrangements were handled in a similar manner during the progress of the Distillation course. Names of lecturers and subjects covered are listed in Tables 1 and 2. (See September issue.)

Members of the classes included some who had scarcely used unit operations since college as well as others who were design specialists on familiar terms with some of the more advanced phases. Obviously, the level of presentation had to be somewhere in between these limits, but yet not discouraging or boring to either extreme of participant. The course design, therefore, included a review of basic principles, with each lecturer starting from scratch, together with selected material to cover more advanced topics.

The Committee was fortunate in obtaining the services of an outstanding group of experts in their respective fields of chemical engineering. Their willingness to come to Charleston on a prearranged date, often at some inconvenience, together with their exceptionally high standards of presentation is gratefully acknowledged. Each lecturer's contribution to the success of these courses cannot be overestimated. Particular recognition belongs to two members of the Charleston Section, Dr. E. H. TenEyck of the DuPont Co., Belle, W. Va., and C. E. McConnell, Jr., Carbide and Carbon Chemicals Co., South Charleston, W. Va., who so ably handled assignments in the Distillation course.

Each lecturer was asked to provide a complete set of notes and appropriate problems for multilith reproduction. The notes and problems were received at least ten days prior to each lecture to allow time for typing, proofreading, and printing. Distribution of each set was made immediately prior to each lecture. A "bonus" in the form of complimentary copies for the Distillation class members of "A Source Book of Technical Literature on Fractional Distillation" was provided through the courtesy of Dr. Paul Foote, executive vice-president, Gulf Research and Development Corp.

The lecture room was obtained through the courtesy of Morris Harvey College, Charleston, and much of the success of the course program was due to its excellent facilities.

(To be cont'd in the September issue)

# INFRARED PROVIDES ACCURATE AUTOMATIC END POINT ANALYSIS for

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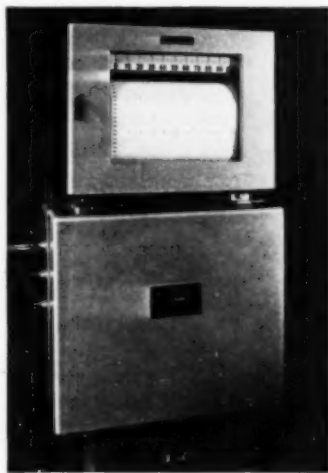
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  - ▶ Through end-point control, the results of such analyses can be used to provide automatic and continuous correction of the process variables.
- ▶ For these reasons, end-point analysis and its control application have become of major significance to the process engineer.
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Write today for Bulletin 36, describing this instrument . . . and for the article "Process Control by End-Point Analysis" from the May issue of Chemical Engineering.

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## CHICAGO MEETING

(Continued from page 23)

and will occupy considerably more than 10,000 ft. of floor space. On display during the entire period of the centennial, they will illustrate the basic factors contributing to the growth and development of this country, with special emphasis on the part engineering has played.

Symposia planned are as follows:

Date	Symposium	Place
Sept. 3	The Role of the Organized Profession	Eighth Street Theatre
Sept. 4	Education and Training	Eighth Street Theatre
Sept. 5	Food	Palmer House Ballroom
Sept. 5	Tools	Eighth Street Theatre
Sept. 8	Transportation	Conrad Hilton Ballroom
Sept. 9		
Sept. 8	Mineral Industries	Hotel Sherman Ballroom
Sept. 9		
Sept. 8	Structures and Construction	Eighth Street Theatre
Sept. 9	Chemical Industries	Eighth Street Theatre
Sept. 10	Engineers Day	
Sept. 11	Communications	Eighth Street Theatre
Sept. 12		
Sept. 11	Energy	Conrad Hilton Ballroom
Sept. 12		
Sept. 11	Health and Human Engineering	La Salle Hotel Ballroom
Sept. 12	Urbanization	La Salle Ballroom

## EXPANSION FOR OAK RIDGE AND PADUCAH

Award of construction contracts for expansion of the U. S. Atomic Energy Commission's gaseous diffusion plants at Oak Ridge, Tenn., and Paducah, Ky., was announced by M. W. Boyer, AEC general manager.

A \$464,000,000 addition at Oak Ridge will be built by the Maxon Construction Co. of Dayton, Ohio. At Paducah, the prime contract on a \$459,000,000 addition to the uranium-235 separation plant now under construction has been awarded to F. H. McGraw and Co., of Hartford, Conn. McGraw is also contractor for the production facilities now being built at Paducah.

Carbide and Carbon Chemicals Co., a division of Union Carbide and Carbon Corp., will operate both new plant additions.

## DO YOU NEED CHEMICAL ENGINEERS?

Approximately sixty chemical engineers are scheduled to be released from active service U. S. Army, at Tooele, Utah, this coming fall. This group has been active as enlisted specialists in the field testing program of the Chemical Corps and is making plans now for civilian employment.

A committee appointed by the home-grown Dugway Technical Society has been appointed to make a group introductory contact by correspondence with interested companies. This committee will assume the duties of a college placement service in making arrangements for interviews and housing accommodations. Any industrial concern interested can contact Ralph F. Peak, 2nd Lt. Technical Detachment Commander, Dugway Proving Ground, Tooele, Utah, or the Dugway Technical Society.

## MANPOWER CONFERENCE

A conference on manpower utilization in national security will be held in Chicago during the Centennial of Engineering, under the auspices of the Engineering Manpower Commission of Engineers Joint Council. The meeting will be in cooperation with the Western Society of Engineers, and will take place Sunday, Sept. 7, in the Grand Ballroom of the Conrad Hilton Hotel.

The opening session in the morning, will see O. W. Eshbach in the chair. Dr. Eshbach is president of the Western Society of Engineers and dean of the Northwestern Technological Institute. The first speaker will be Carey H. Brown, chairman of the Engineering Manpower Commission, manager of manufacturing and engineering services, Eastman Kodak Co., Kodak Park Works, Rochester, N. Y., who will speak on "Manpower Utilization in National Security." There will then be a discussion of the whole problem by a panel which will include Dr. Arthur S. Adams, president, American Council on Education, Hon. William C. Foster, deputy director of defense, Gen. Lewis B. Hershey, director of selective service, Dr. Harry S. Rogers, chairman, Engineers' Council for Professional Development, and J. E. Trainee, vice-president Firestone Tire & Rubber Co.

An afternoon forum will be held also that day at which time those who attended the conference and those interested in manpower questions from every angle, will be able to submit their questions to a panel expert in all phases of the selective service and manpower utilization.

The session will close with a summary by A. C. Monteith, vice-president, Westinghouse Electric Corp.

## CANADA POINTS THE WAY —FENNEBRESQUE

"As long as Canada follows her deeply ingrained traditions of good government and sound control of natural resources, I believe that the chemical industry can expand indefinitely and contribute greatly towards a more abundant life for the people." With these words, John D. Fennebresque, vice-president, Celanese Corporation of America, concluded an address before the Chemical Institute of Canada in Montreal, Quebec, June 2, 1952, in which he discussed Canada's postwar expansion including the development of the chemical and petrochemical industries.

Some of the more important chemical projects, now being constructed in Canada, referred to in the talk, are:

Canadian Chemical Co., Ltd., a division of Canadian Chemical and Cellulose Co., Ltd., is constructing a \$55,000,000 plant at Edmonton, Alta. This plant will produce acetic acid and other organic chemicals as well as cellulose acetate, and staple fiber.

Canadian Industries, Ltd., is constructing two large plants—a \$20,000,000 nylon intermediate unit at Maitland, Ont., and a polyethylene plant at Edmonton.

Dominion Tar and Chemical is building an ethylene glycol unit in Montreal.

British American Oil Co. and Shawinigan Chemical are jointly building a phenol-

acetone plant in Montreal which will utilize a new process.

Shell Chemical Co., is constructing a unit for the production of isopropyl alcohol and acetone at Montreal at a cost of about \$3,000,000.

Bakelite Corp. is building a two-million dollar formaldehyde plant at Belleville, Ont.

Mr. Fennebresque talked at some length on petrochemistry stating that an important factor in the growth of petrochemicals is the development of many new processes and techniques resulting from extensive research and also from the large number of pure raw materials available from petroleum.

Mr. Fennebresque gave considerable credit for the expansion programs now under way to the attitude of the Canadian Government. For example, it examines individual industrial ventures to make sure that they will contribute to the best interests of the nation as a whole.

Its fiscal policies, with comparatively moderate company income-tax laws attract capital investment to Canada. Thereby dependence on imports has been reduced by a decision to process native raw materials and to develop large export markets. He paid tribute to the people—"people who are willing to take chances and subordinate security to the challenge of participating in new daring ventures."



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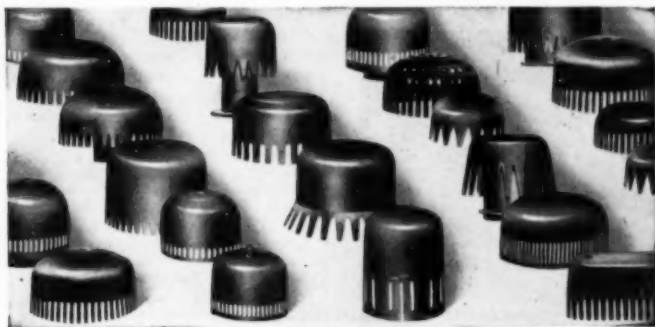
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## DISTILLATION FOR A DAY

### EDITOR'S NOTE

For the same committee, namely, the A.I.Ch.E. Chemical Engineering Education Projects Committee, an industry-sponsored school was organized for one day, May 24, in the Baytown refinery of the Humble Oil & Refining Co. The subject discussed was Distillation. Industry in the Houston area has been cooperative and Humble has stated its intention of putting on another school whenever it is desired.

Last month we covered another such meeting held in New England by the Monsanto Chemical Co. (see page 37). More of these schools are contemplated and arrangements are being made by members of the above-named committee.

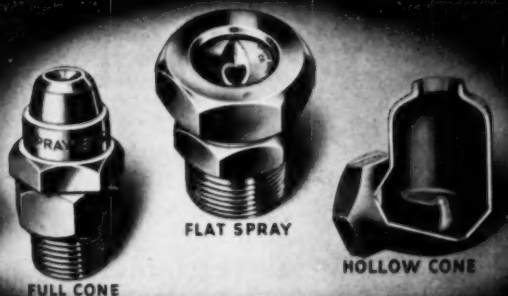
On page 58 of this issue is an account of another "Teach the Teacher" series, an endeavor of the Chemical Engineering Education Projects Committee.

**A**NOTHER industry-sponsored school, this one sponsored by the Humble Oil and Refining Co., Baytown, Tex., was held May 24 by the Chemical Engineering Education Projects Committee of A.I.Ch.E. The subject was Distillation.

Schools represented were: University of Texas; A. and M. College of Texas; Rice Institute; Tulane University; Lamar Tech; University of Arkansas; Louisiana Tech.; and Texas Tech.

The meeting was held at Baytown refinery conference Room A—Research Center, and the program was as follows:

- 9:00 A.M. Introduction—A. A. Draeger
- 9:15 Operation of Bubble - Cap Trays—G. W. Wilson
  - Terminology
  - C. F. Braun Co. Movie
  - Calculation Methods
- 11:00 Plant Testing of Bubble Towers
  - Spilling Indicators
  - Inspection of Light Ends Tower
- 12:15 P.M. Lunch
- 1:30 Review
- 2:00 Design of Bubble Towers—G. T. Atkins
  - Development of Methods
  - Applications
- 3:00 P.M. IBM Fractionation Calculations—W. M. Harp
  - IBM Movie
  - Applications
  - Setting Up Problems
  - Inspection of IBM Machines
- 4:30 Summary
  - Research Problems
- 5:00 Adjourn
- 6:30 Social Hour and Dinner (Houston)



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## FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

*Chairman of the A.I.Ch.E. Program Committee*

Walter E. Lobo, The M. W. Kellogg Co., 225 Broadway, New York 7, N. Y.

### MEETINGS

Chicago, Ill., Palmer House, Sept. 11-13, 1952.

**Technical Program Chairman:** D. A. Dahlstrom, Chem. Eng. Dept., Northwestern University, Evanston, Ill.

Annual—Cleveland, Ohio, Hotel Cleveland and Carter Hotel, Dec. 7-10, 1952.

**Technical Program Chairman:** R. L. Savage, Dept. of Chem. Eng., Case Inst. of Tech., Cleveland 6, Ohio.

Biloxi, Miss., Buena Vista Hotel, Mar. 8-11, 1953.

**Technical Program Chairman:** Norman A. Spector, Vitro Corp., 233 Broadway, New York 7, N. Y.

Toronto, Canada, Royal-York Hotel, April 26-29, 1953.

**Technical Program Chairman:** Brymer Williams, Dept. of Chem. and Met. Eng., University of Michigan, Ann Arbor, Mich.

San Francisco, Calif., Fairmont and Mark Hopkins Hotels, Sept. 13-16, 1953.

**Technical Program Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

**Technical Program Chairman:** R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

### SYMPOSIA

#### Distribution of Chemicals

**Chairman:** D. A. Dahlstrom, Northwestern University, Evanston, Ill.  
**Meeting:**—Chicago, Ill.

#### Monobed Ion Exchange

**Chairman:** F. J. Van Antwerpen, Editor, Chemical Engineering Progress, 120 East 41st St., New York 17, N. Y.  
**Meeting:**—Chicago, Ill.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Walter E. Lobo, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia. Instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman of the meeting, or two to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 70 days before a meeting cannot be considered.

#### Applied Thermodynamics

**Chairman:** W. C. Edmister, California Research Corp., Richmond, Calif.

**Meeting:**—Cleveland, Ohio

#### Human Relations

**Chairman:** R. L. Demmerle, General Aniline & Film Corp., 230 Park Ave., New York, N. Y.

**Meeting:**—Cleveland, Ohio.

#### Modern Statistical Methods in Chemical Engineering

**Chairman:** C. Daniel, Engineering Statistician, 116 Pinehurst Ave., New York 33, N. Y.

**Meeting:**—Cleveland, Ohio.

#### Filtration

**Chairman:** F. M. Tiller, Dir., Div. of Eng., Lamar State College of Technology, Beaumont, Tex.  
**Meeting:**—Cleveland, Ohio

#### High Pressure

**Chairman:** E. W. Comings, Head, School of Chem. & Met. Eng., Purdue University, Lafayette, Ind.  
**Meeting:**—Cleveland, Ohio.

#### Mineral Engineering Techniques for Chemical Engineers

**Chairman:** N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.  
**Meeting:**—Biloxi, Miss.

#### Chemical Engineering in Hydrometallurgy

**Chairman:** John D. Sullivan, Battelle Memorial Institute, Columbus, Ohio.

**Co-Chairman:** John Clegg, Battelle Memorial Institute, Columbus, Ohio.

#### Fluid Mechanics

**Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

#### Absorption

**Chairman:** R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

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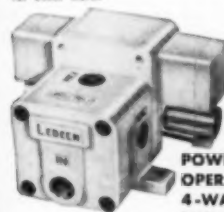
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## LOCAL SECTION NEWS

### TULSA

The Tulsa Section will be host for the annual state Meeting this year and members directing this activity are:

*Chairman*.....T. P. Cook  
*Arrangements*.....P. M. Reynolds  
*Program*.....H. S. Wood  
*Registration*.....R. J. Stancliff  
*Publicity*.....R. H. Jacoby and Glen Davis  
*Finance*.....M. M. Ramer

This one-day meeting will be held at the University of Tulsa Oct. 11. It is planned to have "Petrochemicals" as the main theme. The following papers have been promised at this date:

1. A paper describing the work of Phillips Petroleum Co. on the production of nitrogen chemicals (ammonia, urea, etc.) from natural gas.
2. A paper on shale oil refining by J. D. Lankford of the U. S. Bureau of Mines, Rifle, Colo.
3. A paper concerning the effect of economics on the utilization of LPG by B. R. Carney of the Warren Petroleum Corp., Tulsa.

Other papers are expected concerning ethylene production, acetylene production, polyethylene and low-temperature gasoline plants.

The June meeting featured the start of 1952 competition for the Junior Engineer's Speech Award, the L. K. Cecil Trophy. George M. Rambosch of Stanolind Oil and Gas Co. discussed "The P-V-T-X Relationships in the Binary System, Propane-Hydrogen Sulfide," and Ray. J. Stancliff of The Carter Oil Co. talked on "The Prediction of Packed Tower Performance."

### SOUTH TEXAS

Symposium on hydrocarbons from petroleum, another on fractionation and design, plus a general meeting and a symposium for students, will feature the Seventh Annual Meeting of this Section, to be held Oct. 24 at the Rice Hotel in Houston.

Officers of the organization say that attendance will exceed 500. John J. McKetta, Jr., editorial director of Petroleum Refiner, is general chairman of the meeting.

### NORTHERN CALIFORNIA

At a regular dinner meeting held on June 16 at the Engineers' Club in San Francisco, Prof. H. A. Johnson, of the University of California, discussed "Heat Transfer with Liquid Metals." He described the history of research in this relatively unexplored field, the nature and results of some of the experimental work, and the general character

of this type of heat transfer. Metals used for this purpose include mercury, antimony-bismuth, and the alkali metals. The attendance was approximately sixty-five at this, the last regular meeting until September.

*Reported by D. F. Rynning*

### SABINE AREA

The following officers have been elected for the year 1952-53:

*Chairman*—W. H. Litchfield, Gulf Oil Corp.  
*Chairman-elect*—F. M. Tiller, Lamar College of Technology  
*Secretary-Treasurer*—H. M. High, Jr., Du Pont Co.  
*Executive Committee*—Herman Taylor, Gulf Oil Corp.; D. D. Lee, Du Pont Co.; John Sabot, B. F. Goodrich Co.  
*Retiring Chairman*—S. L. Reebergh, Jr., Gulf Oil Corp.

*Reported by D. J. McCarthy*

### NATIONAL CAPITAL

Officers elected for 1952-53 are as follows:

*Chairman*.....W. T. Read  
*Vice-Chairman*.....D. O. Myatt  
*Treasurer*.....W. D. Kavanaugh  
*Secretary*.....G. A. Schwabland  
*Past Chairman*.....R. D. Sheeline

At the June 23 meeting Carl Setterstrom, sales manager for textile fibers, Carbide and Carbon Chemicals Co., described new synthetic fibers from both their technical and fashion standpoints.

*Reported by D. P. Herron*

### WESTERN NEW YORK

A recent meeting of this Section consisted of a plant trip through the Merckens Chocolate Co., Buffalo, N. Y., which was followed by dinner and refreshments at the Hotel Stuyvesant.

The group saw the manufacture of chocolate, beginning with the cleaning and roasting of the cacao beans through the mixing of the final ingredients to produce sweet chocolate. A group of approximately forty-five engineers and their wives enjoyed the trip.

*Reported by W. C. Greenwald*

### NASHVILLE

The Nashville Society of Chemical Engineers has recently been authorized by Council as a local section of A.I.Ch.E. under the name of Nashville Section. Since January 17, 1952, when Richard N. Lyon of the Oak Ridge National Laboratory, spoke on "Liquid

Metals Heat Transfer" we have had Roy W. Sudoff, associate director of development for the Chemstrand Corp., speak on "Textile Fibers" at a dinner meeting; Chalmer G. Kirkbride, member of the board of directors for the National A.I.Ch.E., speak on "Membership in the National A.I.Ch.E."; Dan May, vice-president of May Hosiery Mill, speak on "Random Thoughts on Our Modern American Economy," and L. S. Davis, rayon process development with the Du Pont Co., speak on "Personal Experiences of an American Engineer in a British Industrial Plant."

Officers elected for the year 1952 were:

Chairman.....E. E. Litkenhous  
Vice-Chairman.....H. J. Kimbrough  
Secretary-Treasurer.....J. C. Katz  
Director for two years.....J. C. Barnett  
Director for one year.....N. A. Copeland

Reported by J. C. Katz

## NEW ORLEANS

At a dinner meeting at the Engineers' and Architects' Club of New Orleans, a group of twenty-five members and visitors heard J. Gordon Wallis, of Napko Paint Co., New Orleans, speak on "Wash Primers." Mr. Wallis pioneered the use of wash primers in the Gulf Coast area.

An announcement was made at the meeting that this Section had accepted society membership in The Engineers' and Architects' Club of New Orleans.

Reported by Alton S. Hall

## ENLISTED SPECIALISTS CHEM. ENGINEERING CLUB

The Enlisted Specialists Chemical Engineering Club held its meeting June 23 at the Army Chemical Center, Md. The guest speaker was Sidney J. Kirkpatrick, of the McGraw-Hill Publishing Co., who addressed some hundred young engineers on the problems facing the young chemical engineer in the profession. Since the audience consisted of young chemical engineers out of college for periods varying from one to five years, the subject was applicable and brought up some pertinent problems of the profession.

The Placement Committee that the Club has recently organized is well under way. Quite a few companies have already been to the Center to interview some of the several hundred enlisted specialists who await separation in the next six months. Companies interested in the service are invited to write to the Club's Placement Committee, Box 100, Building No. 330 at the Chemical Center.



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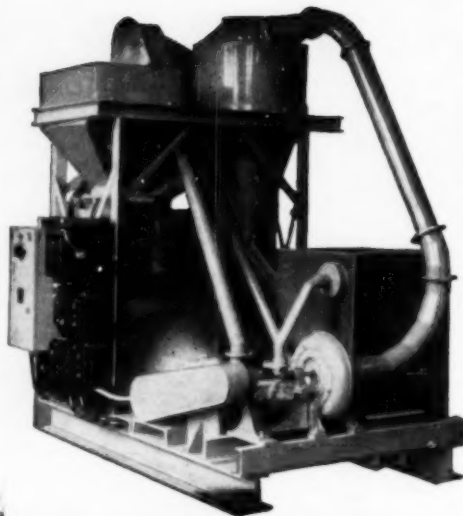
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## PEOPLE

**John J. O'Neill, Jr.**, has been appointed manager of the research and development department of the explosives division of Olin Industries, Inc., East Alton, Ill. He has been with Olin Industries since 1940. Mr. O'Neill graduated from the Missouri School of Mines in 1940 with a B.S. degree, and in 1951 he received his Ch.E. degree.



**John C. Simons, Jr.**, has left his position as section manager, Control Research Section, Westinghouse Atomic Power Division, Pittsburgh, Pa., where for two and one-half years he has been active in the development of nuclear propulsion for submarines. He is now associated with the staff of the Servomechanisms Laboratory at the Massachusetts Institute of Technology where he will continue his work on feedback control systems.

**Lyle F. Albright**, assistant professor of chemical engineering, University of Oklahoma, is serving this summer as visiting professor at the University of Texas, Austin, Tex.

**F. W. Wilson** is now plant manager of the new Thiokol Corp. plant at Moss Point, Miss. Prior to this he was chief engineer at the Trenton, N. J., plant.

### A. S. KLOSS RETIRES

A. Schubert Kloss, manager of production of the naval stores department of Hercules Powder Co., Wilmington, Del., retired July 31. He had been associated with the department's central office in Wilmington, since 1939. Prior to that, he served for nineteen years as manager of a naval stores plant in Brunswick, Ga., manufacturing rosin, turpentine, pine oil, and chemicals derived from them. Mr. Kloss holds a B.S. degree in chemistry from Worcester Polytechnic Institute (1912). He joined Du Pont in June, 1912, as a chemist at the Eastern laboratory in New Jersey. The following year, he became associated with Hercules Powder Co., in California, and in 1914 was made smokeless powder supervisor at the Kenvil (N. J.) plant. Later he became dynamite line supervisor. During World War I he was assistant manager of the company's Parlin (N. J.) plant, then transferred to Wilmington as assistant to the general superintendent of explosives, becoming manager of Brunswick naval stores in 1920.

**K. W. Coons**, head of the department of chemical engineering at the University of Alabama,



has joined the staff of Goshin-Birmingham Mfg. Co., of Birmingham, Ala., on a full-time consulting basis for the summer. Dr. Coons has made numerous contributions to the industries of Alabama. He developed

the Tallol refining processes used by National Southern Products Corp., Tuscaloosa, Ala., of which he is a director. He is vice-president of Warrior Asphalt Corp. and president of Warrior Sales and Development Corp., both Tuscaloosa corporations.

**R. P. Barry, Jr.**, is now assistant superintendent of the new chemicals and plastic resins plant, of Carbide and Carbon Chemicals Co., to be constructed at Seadrift, Tex. Mr. Barry has been, up until now, in the superintendent's department of Carbide's South Charleston (West. Va.) plant as an area supervisor of chemical production. He began with Carbide in 1936 upon graduation from Vanderbilt University with an M.S. degree in chemical engineering. He specialized in ethylene oxide production and became an area supervisor in 1947.

**L. L. Davis** has recently retired as manager of the development and research department of the Continental Oil Co., Ponca City, Okla. He is retained by Continental as a senior research consultant and as such will continue active work on various industrial committees, and organizations, such as the A.S.T.M. and the A.P.I.

**Leon Hecht, Jr.**, recently appointed to the research and development department of the Chemstrand Corp., Decatur, Ala., was formerly with Godchaux Sugars Co. He is a graduate of Vanderbilt University with a B.S. and M.S. degree. During World War II he served with the U. S. Navy.

**Vincent J. Calise** has been named director of the new research and development department created by the Graver Water Conditioning Co., New York. He was formerly associated with Liquid Conditioning Corp., and Permutit Co.

**John Marshall** has recently been transferred from his position as group leader in the research laboratory of the Shell Oil Houston refinery to Shell's Wood River (Ill.) refinery, where he is now manager.

## CURTIS AGAIN HONORED

Francis J. Curtis, past president of the American Institute of Chemical Engineers and vice-president and director of the Monsanto Chemical Co., St. Louis, Mo., was recently elected president of the Society of Chemical Industry of its general meeting in Aberdeen, Scotland. Mr. Curtis is the seventh president elected from the American Section by the parent society formed in England in 1881.

Mr. Curtis lately ended a year's leave of absence from Monsanto during which he served as assistant administrator in the office of the National Production Authority in Washington, D. C., in charge of its chemical, rubber and forest products bureau. Immediately following his graduation from Harvard Mr. Curtis became associated with the Merrimac Chemical Co., South Wilmington, Mass., a company which was later acquired by Monsanto. He transferred to the St. Louis headquarters of Monsanto in 1935 and in 1939 was appointed director of development. He was elected vice-president in October, 1943. In January, 1951, Mr. Curtis was named the winner of the Commercial Chemical Development Association's honor award "in recognition of his 36 years of contributions to commercial chemical development in America."

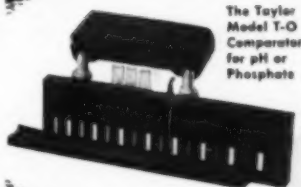
**Jacob M. Geist**, former assistant professor of chemical engineering at M.I.T., was appointed to the department of chemical engineering at the American Technion Society, New York, N. Y. He is a B.S. graduate of Purdue University; he received his M.S. from Penn State College and his Ph.D. from the University of Michigan. A veteran of World War II, Dr. Geist served in the U. S. Army Chemical Warfare Service and as a consultant to a number of corporations, among them the Badger process division of Stone and Webster Corp., Boston, Mass. He was also an instructor at Penn State College and the University of Michigan.

**A. Ralph Thompson** has left the University of Pennsylvania, where he has been associate professor of chemical engineering, to accept the position as professor and head of the department of chemical engineering at the University of Rhode Island, Kingston, R. I. He will continue his association with the Sun Oil Co., Marcus Hook, Pa., as consultant to the technical service section, research and development department.

(More About People on page 72)



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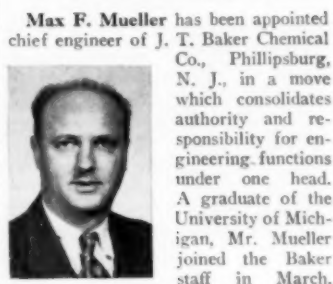
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## PEOPLE

(Continued from page 71)



**Max F. Mueller** has been appointed chief engineer of J. T. Baker Chemical Co., Phillipsburg, N. J., in a move which consolidates authority and responsibility for engineering functions under one head. A graduate of the University of Michigan, Mr. Mueller joined the Baker staff in March, 1951, as manager of the chemical engineering division. Prior to that he was senior process engineer with Blaw-Knox Co.'s chemical plants division, Pittsburgh, and formerly was project engineer with Davison Chemical Corp.'s consulting engineering group in Baltimore. Mr. Mueller served in the armed services during World War II.

**Norman W. McLeod** received an award at the ASTM 50th Anniversary Meeting for his paper entitled "Application of Triaxial Testing to the Design of Bituminous Pavements." This medal is presented for a paper of outstanding merit constituting an original contribution on research in engineering materials. Mr. McLeod is an engineering consultant, Department of Transport, Ottawa, Canada.

**E. J. Fox** is the new plant superintendent of Carbide and Carbon Chemicals Co.'s Texas City plant. He was formerly assistant superintendent. **F. H. Belden**, who was appointed assistant superintendent in March, 1947, is now in charge of raw materials, gas plants, and polyethylene operations, process development and manufacturing office.

**Donald S. Shepherd** has recently received the appointment as divisional vice-president of Winthrop-Stearns, Inc., in charge of its pharmaceutical manufacturing operations at Myerstown, Pa. Mr. Shepherd was, for five years, manager of the Phillips' milk of magnesia plant of Sterling Drug, Inc., Guilford, Miss., of which Winthrop-Stearns is a subsidiary. Joining the Sterling organization in 1936, he was from 1937 to 1947 assistant technical director of the Chas. H. Phillips Co. division plant at Glenbrook, Conn. He is a graduate of Brooklyn Polytechnic Institute with a B.S. in chemical engineering, and took postgraduate work at Columbia University.





William L. Bolles has recently re-joined Monsanto Chemical Co., Texas



City, Tex., as a project leader in the process engineering department. Previously for the past year, he was editorial director of Petroleum Refiner. In his new position he will assume responsibility for process engineering

on a number of projects in connection with Monsanto's current expansion program. Bolles had previously been with Monsanto in its general development department in St. Louis, as well as the Texas division in Texas City. Bolles currently serves as Treasurer of the South Texas Section.

Lester E. Johnson has been appointed product manager of Mathieson Chemical Corp.'s organic chemicals department. Prior to joining Mathieson, he was assistant to the manager, chemical sales development, U. S. Industrial Chemicals Co. He is executive secretary of the Commercial Chemical Development Association and formerly chairman of its public relations committee. A graduate of the University of South Dakota with a B.S. degree in 1933 and the University of Cincinnati with a Master's degree in engineering science in 1938, Mr. Johnson was a production chemist for National Aniline and Chemical Division from 1938 to 1940. From 1940 to 1941 he was with Du Pont Co., and served with the Chemical Corps Technical Command during World War II.

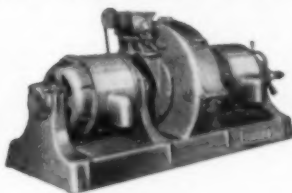
Gerald L. Farrar has recently become the engineering editor of the Oil and Gas Journal. He will be in the Tulsa offices of the Journal and be responsible for the guidance of the engineering program. Farrar has been associate professor of chemical engineering at A. and M. College of Texas for five years. He was graduated from Texas Technological College in 1942 with a degree in chemical engineering. Since that time he has received the M.S. degree in chemical engineering from A. and M. College of Texas, and the professional degree of chemical engineer from Texas Tech. During the war he was engaged in research on production of aviation gasoline with the Magnolia Petroleum Co. in Dallas.



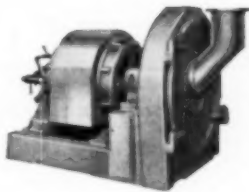
(More About People on page 75)

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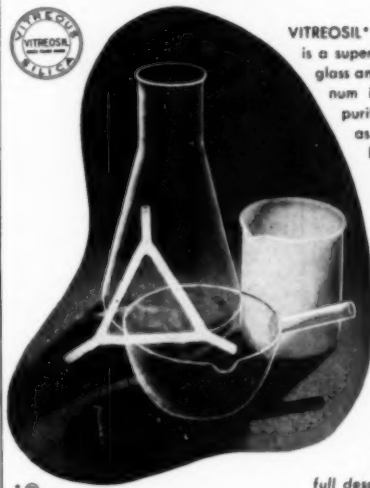
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**CHEMICAL ENGINEER**—M.S. 1947. Tau Beta Pi. Six years' industrial experience, including three years petrochemical research and three years process design and cost estimation. Additional two years' experience in atomic energy project. Box 6-8.

**SALES ENGINEER**—B.S.Ch.E. Presently covering Philadelphia, Wilmington, Baltimore, and Central N. J. for two chemical process equipment manufacturers; handling sales and engineering services and promotional work. Present basis is straight salary and expense, desire to affiliate with an organization willing to add commission to salary and expenses. Box 7-8.

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**CHEMICAL ENGINEER**—Available for employment in India January 1, 1953. B.S.C. in Chemistry (University of Bombay—1948); one year of Law; B.Ch.E. (Iohn Hopkins—1951); M.Ch.E. Brooklyn Polytechnic Institute—1952. Box 9-8.

**CHEMICAL ENGINEER**—B.S., completing M.S. in near future. Three years' industrial experience in research and process development. Desire position in design and/or construction in New York City area. Married, veteran. Box 10-8.

**CHEMICAL ENGINEER**—B.S.Ch.E. June, 1952. Columbia University. Young, energetic, eager to learn. Desire position with a future. N. Y.-N. J. area only. Box 11-8.

**CHEMICAL ENGINEER**—B.S., 1950, Honors. Honor Societies. Age 29, family, veteran. Two years' experience, development and technical service, latex dipped products. Desire position, preferably development, in progressive company with opportunity for advancement and growth. Box 12-8.

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**CHEMICAL ENGINEER**—M.S. Age 34. Desire responsible supervisory position. Several years oil refinery experience, which includes research pilot plant work, process supervision. Specialized in process scale up based on dynamic similitude. Box 15-8.

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**CHEMICAL ENGINEER**—B.Ch.E. 1943. Five years' development and design experience. Veteran, married, three children. Age 33. Desire imaginative position development or production. Box 17-8.

**CHEMICAL ENGINEER**—B.Ch.E. 1949. Age 32, married, two children, veteran. Three years' experience covers antibiotic extraction, engineering study reports, field inspections. Early schooling includes business education. Desire diversified and challenging position. Box 18-8.

## PEOPLE

(Continued from page 73)

**Crawford H. Greenewalt**, president of the Du Pont Co., Wilmington, Del.,



has been chosen to receive the Chemical Industry Medal for 1952, according to an announcement made today by the American Section of the Society of Chemical Industry, donor of the medal. Mr. Greenewalt has been president, chairman of the Executive Committee, and a member of the Finance Committee of Du Pont Co. since 1948, the peak in a career begun in 1922 when he joined the Philadelphia Works of the company as a chemist. He is a graduate of Massachusetts Institute of Technology, where he received a B.S. degree in chemical engineering in 1922.

The Medal was established in 1933 and is awarded annually in recognition of conspicuous services to applied chemistry.

**E. C. Medcalf** has been named head of the coal tar chemicals department, American Cyanamid Co., Calco chemical division, Bound Brook, N. J. In this position he will be in charge of the purchase and sale of coal tar and light oil crudes. Mr. Medcalf received his M.A. degree from Indiana University in 1932. In 1933 he began his career with Calco chemical division as a trainee and shortly became a research chemist, a group leader, assistant chief chemist and production superintendent of coal tar department. He was appointed chief chemist in 1945 and in 1950 was made vice-chairman of Chemicals Department Technical Committees.

**T. H. Dinwiddie** is now with the Oliver Tire and Rubber Co., Oakland, Calif., as a development engineer. In this position he is responsible for the development of new products and processes in relation to mechanical rubber goods manufacture. His former position was plant engineer with the Kaiser Aluminum & Chemical Corp.'s basic refractory plant, Moss Landing, Calif.

**T. R. Harris**, formerly in the engineering sales department of Monsanto Chemical Co., St. Louis, Mo., is still with Monsanto but is now superintendent of the sulfuric acid and sludge recovery plant now being built by Leonard Construction Co. at Avon, Calif. The plant is owned jointly by Monsanto Chemical Co. and Tidewater Associated Oil Co.

(More About People and Necrology on page 76)

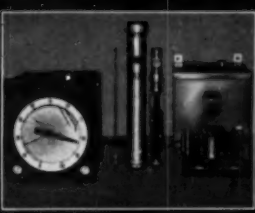


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## PEOPLE

(Continued from page 75)

### MAXWELL AND NASON OFFICERS OF A.S.T.M.

Harold Lee Maxwell, supervisor of mechanical engineering consultants at Du Pont Co., Wilmington, Del., was elected president of the American Society for Testing Materials at its Fiftieth Anniversary Meeting. Howard K. Nason was elected a member on the board of directors.

Dr. Maxwell graduated from Cornell College with a B.S. degree in chemistry. He received his doctorate from Iowa State College and then served as associate professor of chemical engineering at Purdue University from 1926 to 1930. He joined Du Pont in 1930 and during the following years organized three large metallurgical groups. Associated with A.S.T.M. for many years, Dr. Maxwell has served on both technical and administrative committees. During World War II he served on the War Production Board Technical Advisory Committee concerned with materials for chemical equipment. He also participated in technical missions to Europe following the war.

Mr. Nason is research director, organic chemicals division, Monsanto Chemical Co., St. Louis, Mo. From 1932 to 1936 he was chief chemist for Anderson-Stoltz Corp., Kansas City. He became associated with Monsanto Chemical Co. in 1936, first as research chemist, and from 1939 to 1944 was assistant director of research for the plastics division, Springfield, Mass. From 1944 to 1948 he was with the central research department, Dayton, Ohio, becoming director in 1948, and in 1950 was made assistant to Monsanto's vice-president in charge of research, development and patents. He was appointed to his present position in 1951. Mr. Nason received his A.B. in chemistry from the University of Kansas.

Charles W. Hamilton is now associated with the Wyandotte Chemicals Corp., Wyandotte, Mich., in the organic section of the process engineering division. He was formerly with the National Aniline division of the Allied Chemical & Dye Corp., Buffalo, N. Y.

Kenneth R. Nickolls is now a member of the research department of Monsanto Chemical Co.'s plastics division, St. Louis, Mo., as a research engineer. He had been employed for the past four years in process engineering work for General Aniline & Film Corp. at Easton. He holds a B.S. degree in chemical engineering from the University of Illinois (1943) and an M.S. degree in chemical engineering from the University of Michigan (1948).

Max H. Zimmermann, technical director of the Blatz Brewing Co., Milwaukee, Wis., has been promoted to head the expanded research laboratory of the company in addition to his present post. As technical director Dr. Zimmermann handles the formulae and processes as well as the quality control of all Blatz products. Under the new arrangement he will direct all research activities. Dr. Zimmermann joined the organization as technical director in 1948. Previously with Narragansett Brewing Co., Cranston, R. I., he has also been associated with the Schwarz Laboratories, New York, N. Y., and the Firestone Tire and Rubber Co., Akron, Ohio. He attended the University of Tübingen, Würtemberg; University of Hamburg, and the University of Griefswald in Pomerania where he received his Ph.D. degree in 1920. Dr. Zimmermann came to the United States in 1924.

Keator McCubbin, former manager of the fats and oils department, Blaw-Knox Construction Co., Pittsburgh, Pa., is now manager of this same department in Chicago. This new branch is staffed to handle completely a contract—engineering, procurement and construction.

### W. S. LANDES RETIRES

W. S. Landes has recently retired as vice-president of the plastics division of Celanese Corporation of America. He began with the Celluloid Corp. in 1921 and was president of the firm for ten years before it was merged with the Celanese Corp. in 1941. As director of the old Plastics Materials Manufacturers Association and also of the Manufacturing Chemists Association he led the movement to merge the two associations which was finally consummated in 1950. Next year Mr. Landes plans to become a consultant in industrial management specializing in the chemical and plastics industries.

## Necrology

### R. I. BASHFORD

Raymond Irving Bashford, consultant, Olin Industries, Inc., died in Baraboo, Wis., July 19. Early in his career he was associated with the Atlas Powder Co.; first in the operating division and later as assistant to the vice-president. Subsequently he went with the Nickel Alloys Co., Grasselli Powder Co., and the Peerless Explosives Co. More recently he was consultant to Liberty Powder Co., Wabash River Ordnance Works, Newport, Ind. Mr. Bashford received a B.S. in chemistry in 1913 from Syracuse University.

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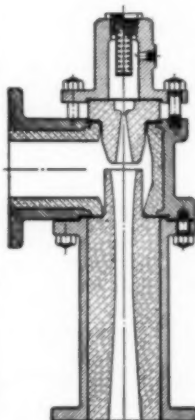
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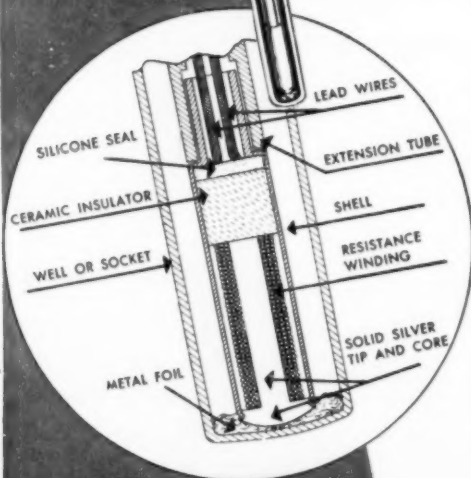
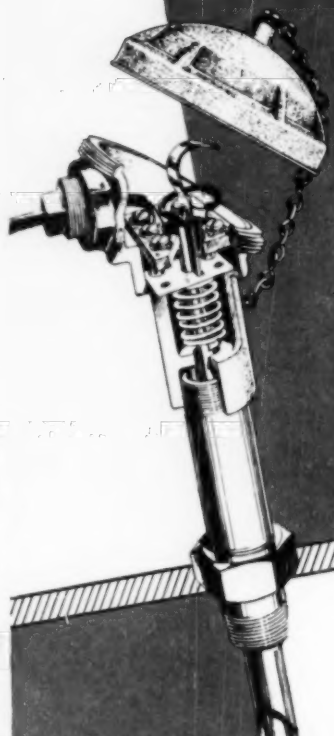
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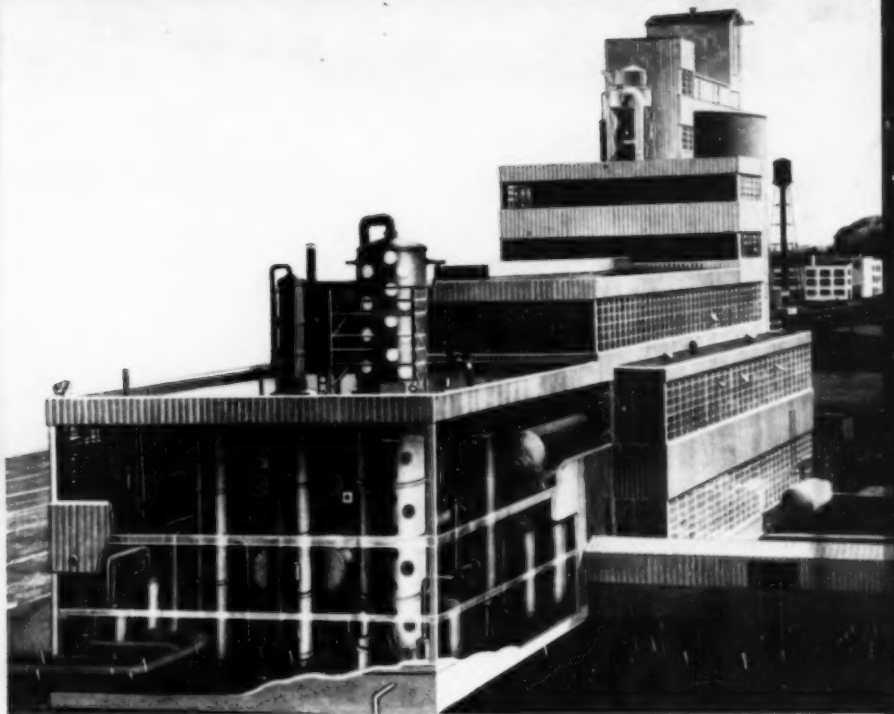
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